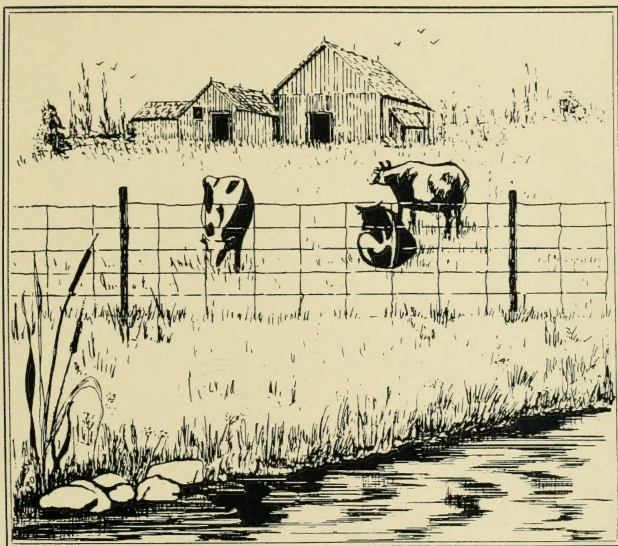


CLEAN UP RURAL BEACHES (CURB) PLAN

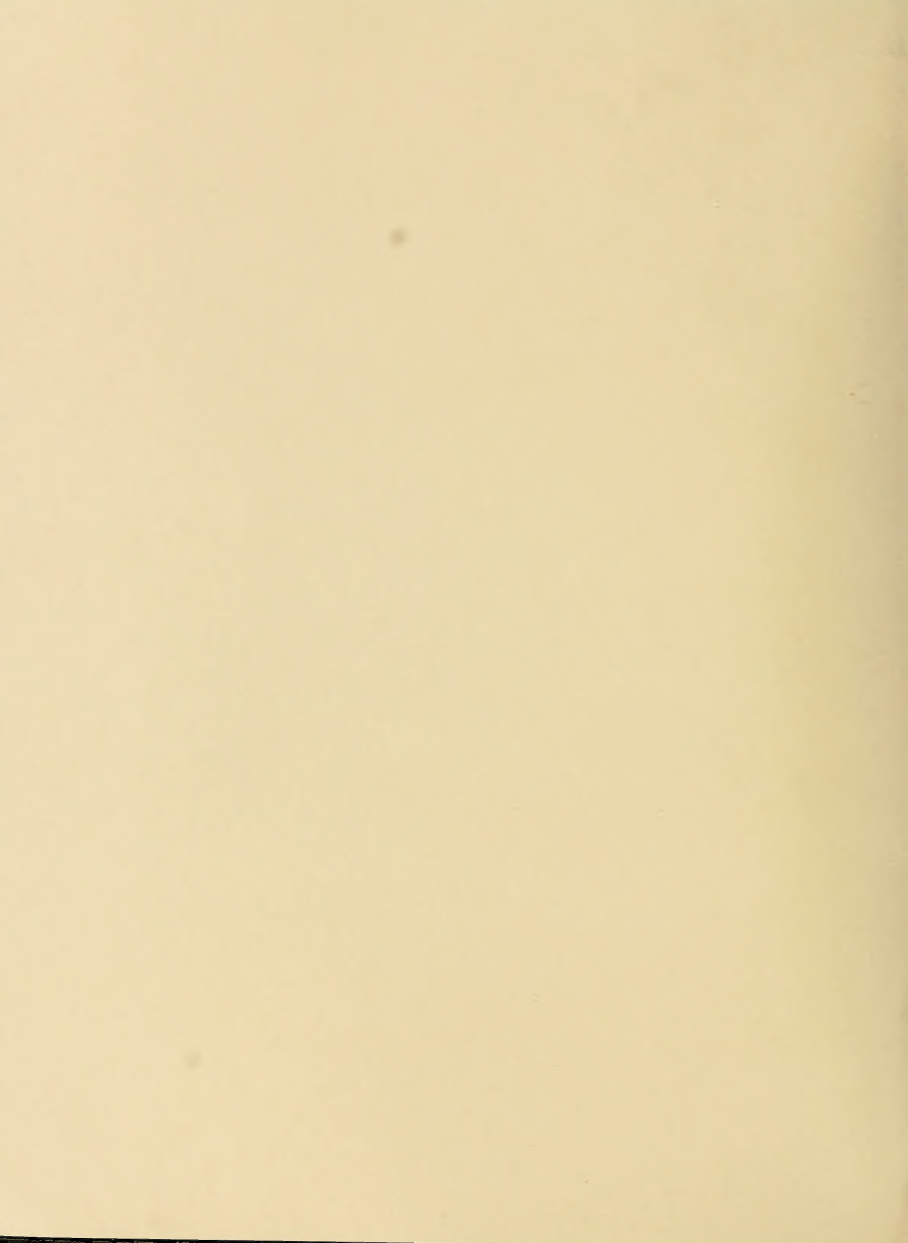
FOR THE EAST HUMBER RIVER,
CENTREVILLE CREEK, AND BRUCE CREEK
WATERSHEDS



PRODUCED BY
THE METROPOLITAN TORONTO AND REGION
CONSERVATION AUTHORITY

FOR THE ONTARIO MINISTRY OF THE ENVIRONMENT

ISBN 0-7729-8651-7



DISCLAIMER

This report has been reviewed by the local Technical Steering Committee and approved for publication. Approval does not necessarily signify that the contents reflect the position and/or policies of individual agencies.

FOREWORD

This report is one of a series produced under the Provincial Rural Beaches Program. The objective of the Program is to identify the relative impact of pollution sources, and develop a course of action leading to the restoration and long term maintenance of acceptable water quality at provincial rural beaches.

Significant enrichment and bacterial contamination in southern Ontario rivers and lakes originates from rural sources. The discharge of waste material to streams can result in elevated bacterial concentrations, nuisance algae blooms, fish kills, and present a potential health hazard to humans and livestock using the water. Watershed studies have found that a multitude of pollution sources and pathways may affect beaches in Ontario. These include:

- 1) Urban sanitary and stormwater runoff,
- 2) Direct livestock manure access to watercourses,
- 3) Inadequate manure management practices,
- 4) Direct discharge of milkhouse wastes,
- 5) Contaminated field tile systems, and
- 6) Faulty septic systems

The impact upon beaches of any of these sources, either singly or in combination, can range from a few days of elevated concentrations to complete seasonal closures.

Numerous beach closings in 1983 and 1984, drew public and government attention to the severity of this water quality problem. In 1985, the Ontario Ministry of the Environment's (MOE) Water Resources Branch formulated the Provincial Rural Beaches Strategy Program. Directed by the Provincial Rural Beaches Planning and Advisory Committee, it includes representatives from MOE, Ministry of Agriculture and Food (OMAF), and Ministry of Natural Resources (MNR).

With financial and technical assistance from the MOE, local Conservation Authorities carry out studies under the direction of a local technical steering committee. Chaired by an MOE regional staff, the committees typically include representation from OMAF, MNR, the Medical Officer of Health, Conservation Authority, the local Federation of Agriculture, and a local farmer. The chairs of the local committees assure communication between all the projects by participating on the Provincial Committee.

The primary objective of each local study is to identify the relative impact of pollution sources, their pathways to beaches, and to develop a Clean Up Rural Beaches (CURB) plan specific to the watershed upstream of each beach. The CURB plan develops remedial strategy options and respective cost estimates for each beach through:

- 1) Field inspections,
- 2) Farmer consultations,
- 3) Water quality monitoring, and
- 4) Basic mathematical modelling techniques.

Recommended actions will include both measures for specific beaches and broader scale Provincial measures based on cumulative results of component studies.

The following related research projects were also MOE funded and undertaken by various Conservation Authorities to improve our understanding of bacterial and nutrient dynamics:

- 1) Insitu bacterial survival studies determine longevity: in watercourses, offshore of beaches, in sediments, and in milkhouse washwater tiles.
- 2) Biotracer studies determine the speed and nature of travel for bacteria introduced into a watercourse.
- 3) A liquid manure spreading study examines bacterial movement through the soil column and exiting field tile drains.
- 4) A target sub-basin study evaluates the effectiveness of a watershed with comprehensive remedial measures.

Numerous demonstration farms have been established with the cooperation of local farmers to display innovative management practices. Research continues on their effectiveness at improving water quality.

Comments and/or questions on this report are welcome. Please send written comments to:

Chairman
Provincial Rural Beaches Planning and Advisory Committee
c/o Environment Ontario
Water Resources Branch
135 St. Clair Ave. W.
Suite 100
Toronto, Ontario
M4V 1P5

Rural Beaches Project
Clean Up Rural Beaches (CURB) Report

Prepared for the Ontario Ministry of the Environment

By Peter Mar

The Metropolitan Toronto and Region Conservation Authority

February 1991

ACKNOWLEDGEMENTS

Technical and financial support for the Metropolitan Toronto and Region Conservation Authority Rural Beaches Project comes from the Provincial Rural Beaches Strategy Planning and Advisory Committee.

The Author greatly appreciates the guidance and input from the MTRCA Rural Beaches Project Steering Committee:

Keith Willson, MOE, Chairman
Steve Maude, MOE
Michael Young, MOE
Michael Toombs, OMAF
Ralph Stanley, Peel Health Department
Harvey Bones, York Health Department
Glenn Atkinson, York Federation of Agriculture
Jim Early, Peel Federation of Agriculture

Additional thanks go out to past Steering Committee members who provided support for research leading up to the CURB Plan:

Doug Miller, OMAF
Tom Willins, Richmond Hill Health Department

Many thanks go to Doug Hocking, ABCA, Garry Palmateer, MOE South West Region, and Dave Hayman, UTRCA, for their information and assistance in developing the CURB model.

The MTRCA appreciates the cooperation of farmers and rural residents within the study watersheds.

LIST OF TABLES

	<u>Page</u>
Table 1: Summary of high pollution potential livestock operations	10
Table 2: Bacteria transportation time in target watersheds	13
Table 3: Percentage of bacterial sources delivered to swimming beaches by watershed	20
Table 4: Claireville and Boyd Conservation Area potential lost revenue from swimming beach closures	33
Table 5: Bruce's Mill and Albion Hills Conservation Areas - Average summer attendance 1980 -1990	35
Table 6: Estimated capital costs of remedial measures to reduce bacterial inputs upstream of the swimming beaches at Bruce's Mill, Albion Hills, and Boyd Conservation Areas.	47
Table 7: Value of manure nutrients	49

LIST OF FIGURES

Page

Figure 1:	Map of study watersheds	2
Figure 2:	Swimming season geometric mean fecal coliform densities	3
Figure 3:	Bruce Creek bacteria production versus delivery to the beach at Bruce's Mill Conservation Area	18
Figure 4:	Dry weather - Predicted versus actual water quality at the Bruce's Mill Conservation Area beach	21
Figure 5:	Wet weather - Predicted versus actual water quality at the Bruce's Mill Conservation Area beach	22
Figure 6:	Centreville Creek - Bacteria source input versus delivery to the Albion Hills Conservation Area beach	23
Figure 7:	Dry weather - Predicted versus actual water quality at the Albion Hills Conservation Area beach	24
Figure 8:	Wet weather - Predicted versus actual water quality at the Albion Hills Conservation Area beach	26
Figure 9:	East Humber River - Bacteria source input versus delivery to the Boyd Conservation Area beach	27
Figure 10:	Dry weather - Predicted versus actual water quality at the Boyd Conservation Area beach	28
Figure 11:	Wet weather - Predicted versus actual water quality at the Boyd Conservation Area beach	29
Figure 12:	Annual summer attendance from June to August 1980 to 1990, at Boyd and Claireville conservation areas	32
Figure 13:	Annual summer attendance from June to August 1980 to 1990, at Bruce's Mill Albion Hills conservation areas	35

Figure 14:	Bruce's Mill Conservation Area - Beach water quality predictions for individual remedial options	52
Figure 15:	Bruce's Mill Conservation Area - Beach water quality predictions for combined remedial options	52
Figure 16:	Albion Hills Conservation Area - Beach water quality predictions for individual remedial options	54
Figure 17:	Albion Hills Conservation Area - Beach water quality predictions for combined remedial options	54
Figure 18:	Boyd Conservation Area - Beach water quality predictions for individual remedial options	56
Figure 19:	Boyd Conservation Area - Beach water quality predictions for combined remedial options	56

LIST OF APPENDICES

- Appendix 1: Clean Up Rural Beaches (CURB) model calculations
- Appendix 2: Bruce Creek (Bruce's Mill Conservation Area) CURB model calculations
- Appendix 3: Centreville Creek (Albion Hills Conservation Area) CURB model calculations
- Appendix 4: East Humber River (Boyd Conservation Area) CURB model calculations
- Appendix 5: Wildlife bacterial estimates

EXECUTIVE SUMMARY

From 1986 to 1989 the MTRCA Rural Beaches Project, in co-operation with the Ministry of the Environment (MOE), investigated the sources of rural water quality impairment that have affected conservation area swimming beaches.

The Clean Up Rural Beaches (CURB) Plan identifies bacterial pollution sources, estimates their impact on water quality, and presents remedial options necessary to improve water quality in the Centreville Creek, Bruce Creek, and East Humber River watersheds.

Stream surveys, field assessments, and water quality monitoring revealed agricultural sources as the primary contributors of beach bacterial pollution. The CURB model estimates that runoff from barnyards, inadequate manure storage facilities, and from unrestricted livestock access to watercourses, account for between 87% and 95% of the bacterial contamination at rural swimming beaches. Faulty septic systems and wildlife account for most of the remaining share.

In an effort to improve water quality, the CURB plan recommends remedial measures to control bacterial pollution sources. These remedial measures include:

- Construct proper manure storages and barnyards (30) to minimize contaminated runoff.

- Fence livestock from watercourses (31).

- Repair faulty septic systems (122).

- Control the numbers of Canada Geese at the swimming beaches.

The estimated costs for these measures are:

Bruce Creek	\$120,000
Centreville Creek	\$586,000
East Humber River	\$2,677,000

Total	\$3,383,000

It is recommended that remedial measures be implemented on the Bruce Creek watershed (headwater of the Rouge River) as a pilot project. It is the smallest watershed, has the fewest problems, and is the least costly to implement. Monitoring water quality will evaluate the effectiveness of remedial measures.

Program delivery by the MTRCA should be provided under the direction of a multi-agency steering committee. The program should offer educational, financial, and technical assistance to the rural community. This effort would promote alternative land management practices that may achieve improved surface water quality.

RECOMMENDATIONS

LIVESTOCK ACCESS

That policy changes be implemented at the provincial or municipal level to restrict livestock access from municipal drains and watercourses.

That the grant program consider financial compensation for pasture land taken out of production.

MANURE MANAGEMENT

That the Ontario Ministry of Agriculture and Food (OMAF) subsidize a manure management course for all landowners who have manure application on their fields. This course must be completed by all licensed custom applicators.

That MOE, OMAF and Authority staff assist farmers to develop a contingency plan to prevent, contain and clean up a manure spill.

That prior to manure storage construction, MOE provide environmental guidelines, individual construction plan approvals and post construction inspection to ensure standards are met to prevent surface or groundwater contamination.

MILKHOUSE WASHWATER TREATMENT

That washwater tank and treatment trench systems are only installed by OMAF certified contractors. (Similar to OMAF approved drainage contractors)

That OMAF initiate research to develop reliable and economical methods for milkhouse washwater treatment (grassed filter strips, artificially constructed wetlands, aeration of discharge, bacterial disinfection, etc.).

That legislative changes be made to the Milk Act, necessitating the Dairy Inspection Branch of OMAF to require milkhouse washwater treatment or handling facilities for Class A milk sales.

PRIVATE SEWAGE SYSTEMS

That the MOE develop a program to inspect and ensure the correct operation of septic systems adjacent to open water, agricultural field drainage tiles, municipal drains, and storm sewers.

That the use permit be renewed at least every three years, upon a septic system inspection indicating proper system maintenance as outlined in the certificate of approval. The inspection will include the emptying of the septic tank, and an examination for gross system malfunctions, such as above ground effluent discharge.

That a certificate of approval be a condition of sale or resale of private or commercial residences.

That sewage haulers provide a maintenance record for each pumped tank to the MOE and to the landowner.

That MOE tighten regulations requiring records of disposal for all sewage haulers.

TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS	i
LIST OF TABLES	ii
LIST OF FIGURES	iii
LIST OF APPENDICES	v
EXECUTIVE SUMMARY	vi
RECOMMENDATIONS	viii
1.0 INTRODUCTION	1
1.1 HISTORICAL WATER QUALITY	3
2.0 BEACH CLOSING HISTORY	4
2.1 BOYD CONSERVATION AREA	4
2.2 BRUCE'S MILL CONSERVATION AREA	4
2.3 ALBION HILLS CONSERVATION AREA	5
2.4 CHLORINATION SYSTEMS	5
3.0 CURB MODEL	7
3.1 MODEL DEVELOPMENT	9
3.11 AGRICULTURAL BACTERIA SOURCES	9
3.12 RURAL RESIDENTIAL BACTERIA SOURCES	11
3.13 WILDLIFE BACTERIA SOURCES	12
3.14 BACTERIAL DISAPPEARANCE IN TRANSPORT	12
3.15 BACTERIA TRANSPORT MODEL	14
3.16 BEACH IMPACT IN DRY AND WET WEATHER	15
3.17 FIELD COMPARISON	17
3.2 MODEL PREDICTIONS	18
3.21 BRUCE CREEK	18
3.22 CENTREVILLE CREEK	23
3.23 EAST HUMBER RIVER	27
3.3 MODEL LIMITATIONS	30

4.0	CURB PLAN REMEDIAL OPTIONS	31
4.1	DO NOTHING	31
4.2	TREAT THE SYMPTOMS	33
4.3	CONTROL THE POLLUTION SOURCES	36
4.31	GUIDE TO RURAL LAND USE	
4.32	IMPROVED MANURE MANAGEMENT	36
4.321	IMPROVED FACILITIES	37
4.322	IMPROVED MANAGEMENT PRACTICES	39
4.33	RESTRICTED LIVESTOCK ACCESS TO WATERCOURSES	40
4.34	MILKHOUSE WASHWATER TREATMENT OR CONTAINMENT	41
4.35	REPAIRING OR REPLACING FAULTY SEPTIC SYSTEMS	42
4.36	MUNICIPAL SEWAGE TREATMENT	42
4.37	WATERFOWL CONTROL PROGRAM	44
4.4	CAPITAL COST TO CONTROL POLLUTION SOURCES	45
4.41	INITIAL AND LONG TERM COSTS	45
4.42	CAPITAL COST FOR REMEDIAL MEASURES	45
4.43	EXPECTED IMPROVEMENTS FROM CONTROLLING POLLUTION SOURCES	46
5.0	CURB PLAN STRATEGY	50
6.0	IMPLEMENTATION PLAN	57
7.0	REFERENCES	61
8.0	APPENDICES	63

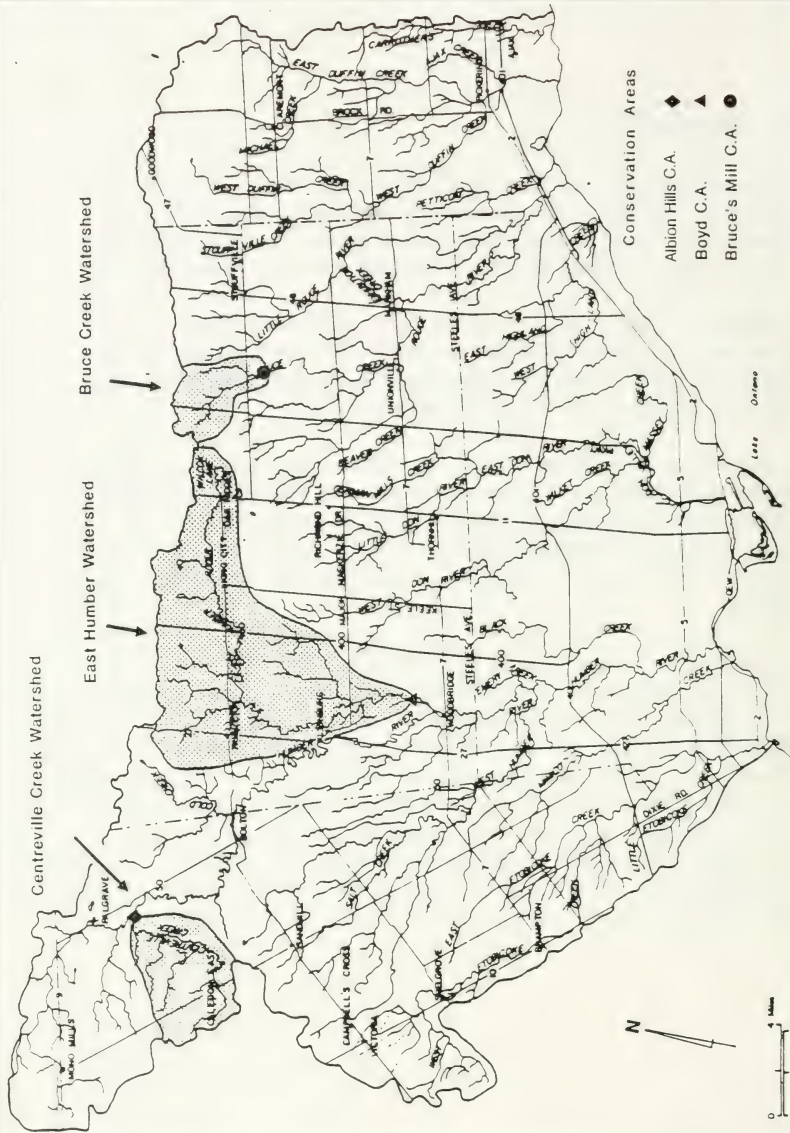
1.0 INTRODUCTION

Poor water quality in the early 1980's caused swimming beach closures in the Metropolitan Toronto and Region Conservation Authority's (MTRCA) rural conservation areas. The closures were primarily due to elevated fecal coliform bacteria concentrations.

In September 1986, the Ontario Ministry of the Environment (MOE) in co-operation with the MTRCA, established the MTRCA Rural Beaches Project to improve water quality at the Boyd, Bruce's Mill, and Albion Hills Conservation Area's (Figure 1).

The principal objectives of the first three years of the Project were to determine the sources and extent of bacterial pollution originating from livestock operations, rural residential and urban sources, and natural inputs. This was achieved through extensive water quality sampling, field studies, and farm surveys.

This report presents the Clean Up Rural Beaches (CURB) Plan, a model which estimates the pollution contribution from various rural sources, and, an implementation strategy with recommendations for remedial measures developed to reduce bacterial pollution at their point of origin. The long-term goal of the Rural Beaches Project is to return beaches to natural swimming without recurrent beach closures at the Boyd, Bruce's Mill, and Albion Hills Conservation Area's, and also, to ultimately provide technical assistance towards improving surface water quality for all the Authority's rural watercourses.



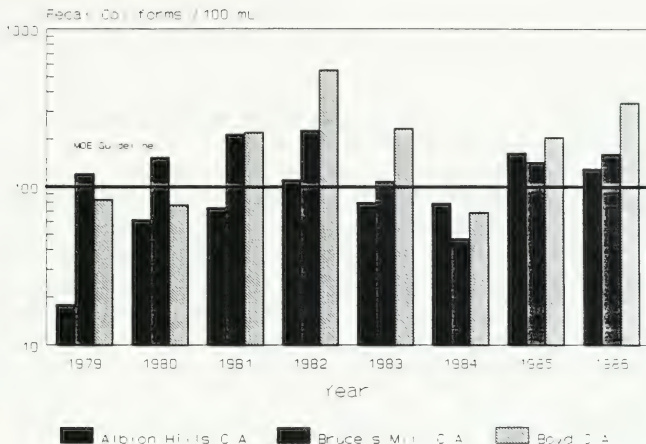


Figure 2: Swimming beach geometric mean fecal coliform densities for 1979 to 1986. Water samples collected from within swimming areas from May to September. Data from local Public Health Offices.

1.1 HISTORICAL WATER QUALITY

Bacterial water quality data collected for the Boyd, Bruce's Mill, and Albion Hills conservation area's, from 1979 to 1986 are presented in figure 2. The geometric mean fecal coliform densities at Bruce's Mill exceeded the Provincial Water Quality Objective (PWQO, 1984) of 100 fecal coliforms per 100ml of water (100 FC/100ml), for seven out of eight years. At Boyd similar results occurred for five years. Although the water quality at Albion Hills was the best of the three conservation areas, it suffered sporadic beach closures in the 1980's. Poor water quality forced the permanent closure of Claireville Conservation Area swimming beach in 1984.

2.0 BEACH CLOSING HISTORY

2.1 BOYD CONSERVATION AREA

The swimming pond at Boyd was created by semi-impoundment of the East Humber River and occupied 0.8 ha.

From the mid 1970's until 1984, bacterial densities frequently exceeded the MOE's Provincial Water Quality Objectives forcing beach closures at Boyd. The problem peaked when the beach opened on May 26, 1983 and was posted by the second week of June due to high bacterial levels. After three weeks of continuous samples that exceeded the Provincial Water Quality Objectives, the beach was closed on July 4, 1983.

Water testing continued through the remainder of the 1983 swimming season and during the summer of 1984. However, consistently high levels of bacteria forced the permanent closure of the beach at Boyd.

2.2 BRUCE'S MILL CONSERVATION AREA

Located in the headwaters of the Rouge River watershed, the swimming beach was created in 1963 by impounding the Bruce Creek. The pond covers an area of 1.2 ha, while the swimming area is regulated to 0.5 ha.

In the late 1970's sporadic beach closures occurred each summer. They increased in frequency and peaked in 1981 when virtually all samples after June 16 exceeded the Objectives for safe swimming.

On June 24, 1985 the chlorination beach curtain system began operation. By maintaining adequate residual chlorine levels within the confined swimming area, the FC densities remained low,

even when water samples exceeded 100 FC/100ml beyond the swimming area.

2.3 ALBION HILLS CONSERVATION AREA

The swimming area in the Albion Hills Conservation Area is formed by impounding Centreville Creek. Sand is imported every 2 years to maintain the beach. The swimming area occupies approximately 0.81 ha.

Beach closures due to high fecal coliform bacterial levels have occurred since the late 1970's. On July 18, 1986 the Authority began operating a chlorination beach curtain system at Albion Hills.

2.4 CHLORINATION BEACH CURTAIN SYSTEMS

Chlorination systems were designed and installed by the MTRCA to maintain water quality at acceptable levels for recreational use. They consist of a heavy vinyl curtain that confines chlorine to the swimming area and a recirculating chlorination system. Water is drawn into a pump-house where chlorine is added. It is then recirculated into the swimming area through several regularly spaced diffusers.

These systems allow continued operation of the facilities while the pollutant source problems are being addressed. Except for infrequent mechanical difficulties, the systems have maintained more than adequate water quality for beach swimming since their installation.

The systems have demonstrated good reliability, are relatively simple to construct and operate, and are cheaper than swimming

pools. However, as a semi-natural swimming area they have a number of disadvantages. The first is the annual maintenance and operation costs. The curtains must be installed, removed, cleaned and repaired annually. The chlorination circulation systems require regular maintenance and must be winterized at the end of each swimming season.

Although the MOE Provincial Water Quality Objectives (PWQO) for fecal coliform bacteria are achieved by chlorination, the curtains confine beach sediment raised by swimmers. A hazard results from suspended sediment that reduces the visibility of submerged swimmers in need of assistance. The PWQO guideline for water clarity requires the bottom of the bathing area to be visible or at least have a secchi dish transparency of 1.2m. This is often unobtainable in the chlorinated swimming areas.

Ultimately, correcting the sources of bacterial pollution and returning the beaches to natural swimming would provide the safest swimming environment.

3.0 CURB MODEL

In 1987 the MTRCA Rural Beaches Project steering committee requested that bacterial pollution from all sources be evaluated and quantified. It was concluded that a model be produced to determine the relative impact of various pollutant sources on swimming beach water quality. Field data for the model were collected from livestock operation surveys, airphoto analysis, stream assessments, and continuous water quality monitoring (Hubbard et. al. 1987 and 1988).

Also in 1987, the Provincial Rural Beaches Program commissioned Ecologistics Limited (1988) to produce the Pollution from Livestock Operations Predictor (PLOP) Model. It predicts individual farm pollution inputs into the nearest watercourse, on a seasonal basis, for fecal coliforms, fecal streptococci, and phosphorus. The PLOP model was used by the MTRCA as a simple method for determining the local impacts from individual livestock operations. However, a bacteria transport model was required to translate PLOP model data into swimming beach water quality.

Models from other rural beaches programs were evaluated. They used custom algorithms, and modified Plop model algorithms were applied, but not the PLOP model itself (Hocking 1989, Hayman 1989, and Ryan 1989). Each authority had designed and calibrated their own bacteria transport model to calculate bacterial impacts on beach water quality. The models were generally similar to each other, but, none were directly applicable to the MTRCA. They had used subwatersheds as their smallest unit of evaluation, while the MTRCA pollutant inputs were calculated for individual farm operations.

A cursory evaluation of hydrologic models revealed the most promising to be the QUALHYMO continuous simulation model (Rowney

and Wisner, 1986), due to its ability to model bacteria as a first order decay contaminant. However, it was ruled out because it would have required gathering additional hydrologic data, and recalculating incompatible pollutant loadings outputted from the PLOP model.

It was decided to create an MTRCA CURB model with a pollution transport model based upon available data, and PLOP model outputs already calculated. The model combined features and algorithms from existing models of the ABCA (Hocking, D. and D. Dean, 1989), MVCA (Fuller, R. and M.E. Foran, 1989), and UTRCA (Hayman, D.G., 1989). The MTRCA CURB model estimates the fecal coliform bacterial loads from rural and suburban sources, and their impact on receiving swimming beaches.

The model calculates:

- A) The bacteria load transported to the beach from each source on individual livestock operations:
 - 1. Livestock access to watercourses
 - 2. Manure storage runoff
 - 3. Barnyard runoff
 - 4. Milkhouse washwater

- B) The watershed bacteria load transported to the beach from:
 - 1. Manure spreading
 - 2. Rural septic system failures
 - 3. Wildlife
 - 4. Suburban septic system failures *
 - 5. Suburban storm sewer runoff *

* Suburban septic system failures and suburban storm sewer runoff from, Oak Ridges, King City, and Nobleton were modelled as two point source pollutant inputs for each community.

3.1 MODEL DEVELOPMENT

3.11 AGRICULTURAL BACTERIA SOURCES

Pollution from Livestock Operations Predictor (PLOP) Model

Bacteria runoff from barnyards, manure storages, milkhouse washwater discharge and livestock access were calculated for each high priority farm with the Pollution from Livestock Operations Predictor (PLOP) model (Ecologistics, 1988).

Field surveys and farm site visits were conducted from September 1986 to May 1989 (Hubbard et. al. 1987 and 1988). Over 100 livestock operations were surveyed in our target watersheds. Forty four (44) high pollution potential farms were inspected to gather specific data for the PLOP model. These were farms with visible evidence of:

1. Contaminated runoff from barnyards and manure storages into surface waters
2. Livestock access to watercourses
3. Improper milkhouse washwater disposal

Table 1 contains the summary of high pollution potential livestock operations. Farms with low pollution potential were not included in the CURB model.

Bacterial contribution from manure spreading, livestock pastures adjacent to water courses and tile drainage were not covered by the PLOP model. Separate estimates for manure spreading and livestock pastures were calculated for each watershed (Appendices 1 to 4), based upon conclusions from the MOE CURB Plan Workshop (Kempenfelt, 1987).

Although it can convey substantial bacterial loads, field tile discharge was not modelled, due to a lack of field data. Interviews with farm operators revealed 39% had tiled fields, however, less than one percent indicated manure spreading on them (Hubbard et. al. 1988).

Calculations for bacterial contamination from agricultural sources can be found in Appendices 1 through 4.

Table 1: Summary of high pollution potential livestock operations

Study Watersheds	Bruce Creek	Centreville Creek	East Humber River
Study Area (km ²)	18	44	178
Watercourse length (km)	24	36	233
Farm Bacteria Sources			
Number of high priority Livestock operations	5	9	25
Livestock Access	4	7	20
Barnyard/Manure Storage Runoff	2	9	19
Milkhouse washwater	-	1	3

3.12 RURAL RESIDENTIAL BACTERIA SOURCES

Failed Septic Systems

Failed septic systems are defined as those that have surface "blowouts", or direct connections to subsurface tiles or storm drains leading into a watercourse or municipal drain. The bacterial load of failed septic systems from rural residences and suburban communities was based upon a theoretical three percent failure rate. This is the upper nominal failure rate of septic systems in York Region (Harvey Bones, pers. comm.). Farm surveys and field inventories were not initially directed to investigate faulty septic systems. In streambank surveys of over 100 farms, only one ostensibly failed septic system was found. Water quality monitoring in the towns of Oak Ridges and King City revealed very high bacterial concentrations of fecal coliforms and Pseudomonas aeruginosa (Hubbard et. al., 1988). This indicates the possibility of illegal connections of sewage lines into stormsewers.

Based on conclusions by other Rural Beaches Programs, where failure rates may be from 30% to 60%, the actual failure rate in the MTRCA study watersheds may be higher than three percent (Fuller and Foran, 1989, Hocking and Dean, 1989, and Hayman, 1989). An accurate assessment would require a septic system survey of each watershed.

Stormsewer Runoff

Although water sampling revealed high Fecal coliform and Pseudomonas aeruginosa densities from storm sewers in the towns of Caledon East, King City and Oak Ridges, no systematic field investigation was conducted. Storm sewer runoff was considered important in the East Humber River watershed only. Consequently,

bacterial runoff was estimated for the towns of Nobleton, King City and Oak Ridges. Bacterial contributions from suburban storm sewer runoff were based on literature values from Marsalek et. al. (1985).

3.13 WILDLIFE BACTERIA SOURCES

Wildlife bacterial sources were included in the CURB model, due to the relatively large area of potential habitat and possible contribution from these sources. This component was confined to beavers and muskrats throughout the watershed, and to Canada Geese at the swimming beaches. A lack of information on other potential wildlife sources prevents their inclusion.

The wildlife bacterial loads were based upon estimated populations located along the length of each watercourse. Canada Geese contributions were estimated by their summer beach populations as observed by conservation area staff at Albion Hills and Bruce's Mill (Appendix 5).

Diffuse Source Bacterial Transport

Manure spreading, rural septic systems (in Bruce and Centreville Creek), and wildlife, are diffuse bacteria sources that originate from the entire watershed. In order to keep the model simple, these were modelled as individual inputs. For example, the total watershed wildlife bacterial load, was modelled as a single source generated in the middle of the watershed (Table 2).

3.14 BACTERIAL DISAPPEARANCE IN TRANSPORT

The measure of bacterial reduction during downstream transportation will be referred to as the disappearance rate. When bacteria enter a watercourse they are subject to a number of factors that reduces their numbers.

Table 2: Bacteria Transportation time in study watersheds

Study Watersheds	Dry weather transport time in hours from		Wet weather transport time in hours from	
	Headwater:	Middle:	Headwater:	Middle:
Bruce Creek	50	24	17	8
Centreville Creek	35	16	19	9
East Humber River	161	72	81	36

In-stream experiments on Centreville Creek and the East Humber River from the MTRCA-LSRCA bacteria survival study (May 1987 to June 1989), found bacterial mortality rates averaged 0.35 logs/day. However, the bacteria diffusion chambers used in this study may have filtered out bactericidal wavelengths of sunlight (G. Palmateer, MOE, pers. comm. 1990). The chambers may also have provided physical protection for the bacteria. Thus, actual bacteria mortality may have been underestimated.

In the MTRCA biotracer field experiments on Centreville Creek, known concentrations of a tracer bacteria, Nalidixic Acid resistant Escherichia coli, were introduced into the watercourse and sampled at specific locations as the bacteria flowed downstream. Bacterial loss rates as high as 7.2 logs/day or 0.30 logs/hour were found (April, 1989). This high rate may be a function of bacterial mortality from sunlight and bacterial sedimentation in areas such as pools and slow reaches of the creek. The actual disappearance rate would probably be smaller if subsequent resuspended bacteria were accounted for.

CURE Model Disappearance Rate

For the purposes of this model the estimated bacteria disappearance rate is 0.7 logs/day, or 0.029 logs/hour, which is twice the average mortality rate found in the bacteria survival study and one tenth the disappearance rate of the biotracer study.

3.15 BACTERIA TRANSPORT MODEL

The bacteria transport model determines the impact of each pollutant source on beach water quality. By estimating the transportation time of bacteria from its source to the beach, under dry and wet weather conditions, bacterial disappearance can be calculated. A beach bacterial load from each upstream source results.

The beach impact from each bacterial source was calculated as follows:

Bacterial load - (travel time to beach x disappearance rate)
= Beach bacterial load for each source

e.g. $(2.42 \times 10^{12} \text{ FC/92})77 - (35 \text{ hours} \times 0.029 \text{ logs/hour})$

FC load from	Dry weather	FC disappearance
livestock	travel time	0.029 logs/hour
access on		or 0.7 logs/day
farm # 15 EHR		

= 1.97×10^{11} FC

= Estimated fecal coliform bacteria load transported from the livestock access site on Farm #15 to the Boyd C.A. beach, during summer dry weather.

3.16 BEACH IMPACT IN DRY AND WET WEATHER

The effects of combined upstream bacterial sources on the beach swimming area were simulated three ways in each watershed:

1. Summer dry weather (low flow) bacterial loads
2. Summer wet weather (high flow) bacterial loads
3. Total summer bacteria loads (the sum of 1 and 2)

For the purpose of this report the summer season is defined as June 15 to September 14. This is standardized with the PLOP model (Ecologistics, 1988) to eliminate data conversions. It was assumed that 13 days of the 92 day summer season would have precipitation greater than 5mm, or enough to generate runoff from the study watersheds (D. Haley, MTRCA., pers. comm.). Thus 13 days have wet weather and high flow conditions. Dry weather, or low flow conditions, occurs during the remaining 79 days.

This division separates the bacterial contributions from constant flow sources such as livestock access and failed septic systems into dry and wet weather units. For continuous sources, the bulk of their 92 day summer bacterial contribution, will come from dry weather inputs (79 days). The remaining 13 days will be wet weather inputs.

The dry weather sources deliver continuous bacterial loads to a watercourse. In this CURB model dry weather contributors to beach contamination are:

1. Livestock access to watercourses
2. Milkhouse washwater
3. Rural septic system failures
4. Suburban septic system failures
5. Wildlife

Wet weather bacterial sources are created by rainfall carrying potentially contaminated runoff into watercourses. Runoff during wet weather conditions convey all dry weather sources and the following additional inputs:

6. Manure storage runoff
7. Barnyard runoff
8. Manure spreading runoff
9. Suburban storm sewer runoff

Total summer bacterial loads reveal the total seasonal contribution to the beach for each source. The total annual bacterial loads were also calculated for comparison purposes (Appendix 1 to 3). Although contaminants contribute to water quality degradation throughout the year, the impacts to recreational water quality are limited to the swimming season, from the end of May to the beginning of September.

In natural systems, slow stream velocities during dry weather are conducive to sedimentation of bacteria, and bacteria bound to suspended sediment particles. It is likely that the simple formula used in this model will overestimate the dry weather bacterial transport, because bacterial sedimentation was not accounted for. Conversely, under wet weather, increased stream velocities will entrain streambed sediment and resuspend bacteria into the water column. Bacteria deposited during dry weather conditions will subsequently be re-introduced into the watercourse along with the wet weather input sources. Thus, the model will likely under predict wet weather bacteria transported to the beach.

3.17 FIELD COMPARISON

The CURB model predictions were compared to samples collected at the Bruce's Mill and Albion Hills swimming areas, and in the East Humber River near Boyd Conservation Area. Two samples were collected from outside of the chlorinated area. Initial samples were taken from 0.3m below the surface of the water. A second sample was collected after intentional disturbance and resuspension of bottom sediments. The disturbed sample attempts to mimic effects of normal swimming activity and often exhibit greater bacterial densities than undisturbed samples.

3.2 MODEL PREDICTIONS

3.2.1 BRUCE CREEK

Figure 3 displays the bacteria input at its source and delivery to the beach under dry and wet weather conditions. The principal contaminant source is runoff from barnyards and manure storages.

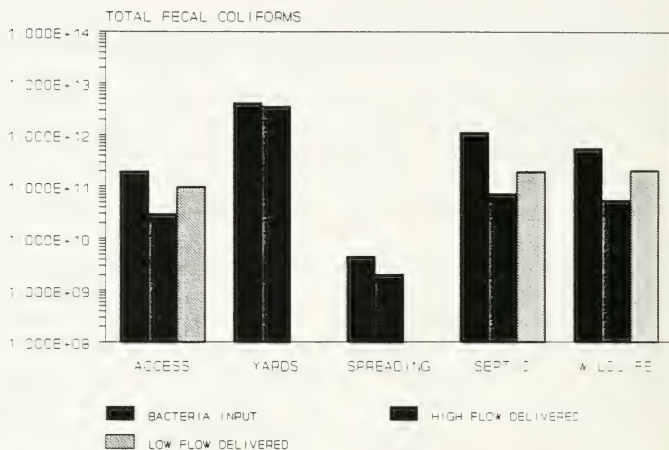


Figure 3: Bruce Creek - Bacteria source input versus bacteria delivered to the Bruce's Mill Conservation Area beach.

It is evident for livestock access, septic system failures and wildlife, that the bacteria delivered is higher during dry weather than wet weather. In the CURB model, continuous flow sources have their 92 day summer bacterial contributions divided into 79 dry and 13 wet days. Thus, the majority of bacteria from these sources are discharged under dry weather. The relatively

large losses for spreading, wildlife and septic systems, are due to the relatively long bacterial delivery time (eight hours) from the watershed midpoint. Farms with livestock access and runoff from barnyards and manure storages, are located within four hours (wet weather) of the beach. Bacterial loss is small and the impact from these sources is large, due to the short travel time.

Summer dry weather model

The CURB model predicts wildlife (42%) and septic system failures (39%) as the primary bacterial contributors under dry weather conditions. Livestock access accounted for the remaining 20% (Table 3).

The Bruce Creek CURB model predicts a range of summer dry weather beach concentrations between 93 and 186 fecal coliforms / 100 ml. When compared to field samples (figure 4), the geometric mean of undisturbed pond samples outside of the chlorinated beach area was 145 FC/100 ml, falling within the predicted range. However, the geometric mean of 412 FC/100 ml for disturbed samples is above the predicted range.

The individual samples show a rising trend that peaks between late July and early August. The highest individual sample on Aug 10, 1987 was 2600 FC/100 ml, 14 times higher than the upper model prediction range. The bacterial concentration of disturbed water samples almost always exceeded the undisturbed samples, with 3700 FC/100 ml on Aug 25, 1987 exceeding the model's predicted range by 20 times.

Summer wet weather model

Shown in Table 3, the primary wet weather bacteria source is runoff from barnyards and inadequate manure storage facilities (96%). The model predicts bacteria from livestock access to

Table 3: Percentage of bacterial sources delivered to swimming beaches by watershed

	Bruce Creek	Centreville Creek	East Humber River
Summer low flow sources			
Livestock access	20 %	21 %	90 %
Milkhouse washwater	-	-	0 %
Septic system failures	39 %	34 %	8 %
Wildlife	42 %	45 %	2 %
	-----	-----	-----
Total	100 %	100 %	100 %
Summer high flow sources			
Livestock access	1 %	1 %	6 %
Barnyards and storages	96 %	97 %	89 %
Milkhouse washwater	-	-	0 %
Manure spreading	0.05%	0.1%	0.1 %
Septic system failures	2 %	1 %	3 %
Storm sewer runoff	-	-	2 %
Wildlife	1 %	1 %	0.4 %
	-----	-----	-----
Total	100 %	100 %	100 %
Total summer sources			
Livestock access	3 %	3 %	16 %
Barnyards and storages	84 %	87 %	79 %
Milkhouse washwater	-	-	0 %
Manure spreading	0.1%	0.1 %	0.1 %
Septic system failures	6%	4 %	3 %
Storm sewer runoff	-	-	1 %
Wildlife	6 %	6 %	0.5 %
	-----	-----	-----
Total	100 %	100 %	100 %

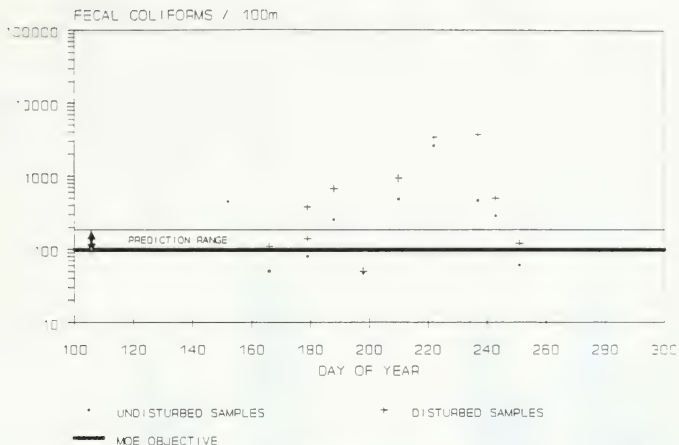


Figure 4: Dry weather - Predicted versus actual water quality at the Bruce's Mill Conservation Area beach. Water samples were collected under undisturbed and disturbed sediment conditions. 1986-89

decrease to one percent (1%). Wildlife contribution decreases to one percent (1%) and septic system failures are estimated by the model to contribute two percent (2%) of the total bacteria under wet weather conditions.

When compared to field samples at the beach (figure 5), the geometric mean of both undisturbed (824 FC/100 ml) and disturbed samples (1441 FC/100 ml) fall into and above the CURB model prediction range of 329 to 1317 FC/100 ml, respectively. The highest recorded wet weather samples at the beach were on July 14, 1987, when the undisturbed sample was 3700 FC/100 ml and the disturbed sample was 6800 FC/100 ml. Both samples exceeded the upper model range by three and five times respectively.

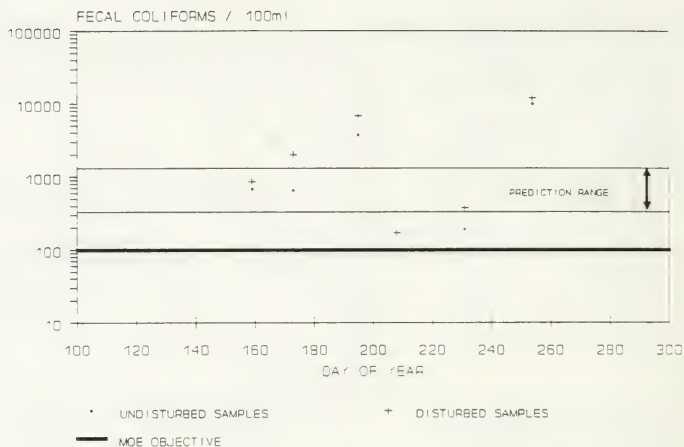


Figure 5: Wet weather - Predicted versus actual water quality at the Bruce's Mill Conservation Area beach. Water samples were collected under undisturbed, and disturbed sediment conditions. 1986-89.

3.22 CENTREVILLE CREEK

Figure 6 displays the bacteria production and delivery to the beach by source under dry and wet weather conditions. The results are lower in magnitude, but generally quite similar to the Bruce Creek estimates.

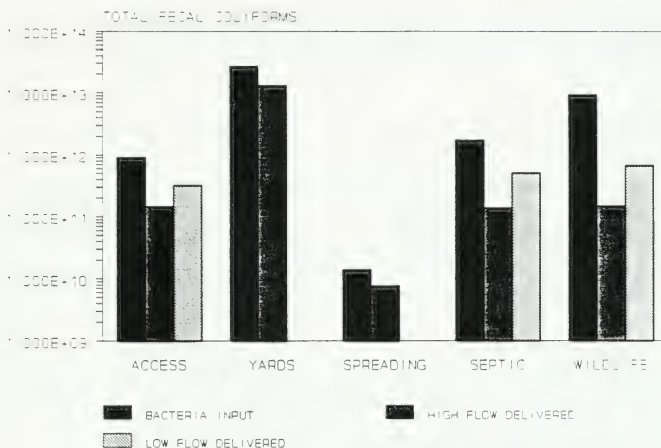


Figure 6: Centreville Creek - Bacteria source input versus bacteria delivered to the Albion Hills Conservation Area beach.

Summer dry weather model

The CURB model predicts wildlife contributes 45% of the summer dry weather bacteria. This is followed by septic system failures at 34% and livestock access at 21% (Table 3).

The wildlife bacterial load estimate is substantial in dry

weather conditions. There is a vast amount of the Centreville Creek watershed that is good wetland habitat. Most of the watercourses in the watershed have well vegetated streambanks and relatively little direct disturbance. Although these are estimated sources, numerous beaver dams exist along Centreville Creek, and are under constant scrutiny by residents adjacent to the Creek.

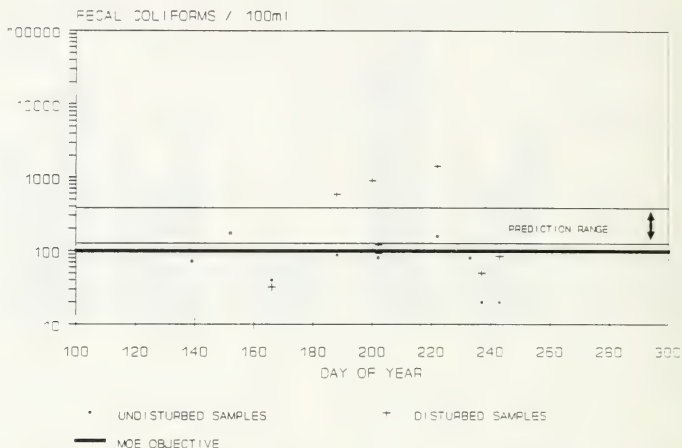


Figure 7: Dry weather - Predicted versus actual water quality at the Albion Hills Conservation Area beach. Water samples were collected under undisturbed and disturbed sediment conditions. 1986-89.

The Centreville Creek CURB model predicts the range of summer dry weather bacterial concentrations to lie between 126 and 379 FC/100 ml (Figure 7). The prediction is higher than the actual geometric mean of 67 FC/100 ml for undisturbed water samples.

But, the disturbed sediment geometric mean of 191 FC/100 ml falls into the middle of the prediction range.

As in Bruce Creek, individual field sample bacterial densities rise in early summer and peak in late July and early August. The disturbed sediment samples almost consistently exceed the undisturbed samples by almost an order of magnitude. The highest single disturbed sediment sample was 1420 FC/100 ml recorded on August 10, 1987. This exceeded the upper range of the model by almost four times.

Summer wet weather model

Agricultural sources become dominant under wet weather conditions, totalling 98% of the bacterial pollution sources. Wildlife decreases to one percent (1%) and septic system failures becomes 1% (Table 3). The majority of agricultural bacteria originates as runoff from barnyards and inadequate manure storage systems.

Storm sewer inputs from Caledon East were not contributors to the CURB model because the town is located upstream of Innis lake and Belcon pond. These water bodies are a kettle lake complex that act as a buffer to filter out bacteria and sediment (Hubbard et. al., 1988). Agricultural sources upstream of Innis Lake were not modelled for the same reason. This does not suggest that these sources are unimportant. In fact, several stormsewer outfalls in Caledon East should receive attention regarding potential illegal septic system connections. Manure management practices on two farms may cause severe local water quality problems. However, bacteria from these sources do not appear to travel through Innis Lake and impact the beach at Albion Hills.

From 1987 to 1989, water samples from Centreville Creek in the town of Caledon East had dry and wet weather geometric mean

densities of 763 and 1028 FC/100 ml respectively. The geometric mean density of a stormsewer outflow at Airport Road was 3913 FC/100 ml, over seven wet weather samples. For the same period, at the outlet of Innis Lake where Centreville Creek continues, the dry and wet weather geometric means were 10 and 42 FC/100 ml. These are the lowest bacterial densities on the main branch of Centreville Creek.

The wet weather predicted range of 1206 to 4824 FC/100 ml is well above the actual swimming pond undisturbed and disturbed geometric means of 217 and 639 FC/100 ml (Figure 8). Most of the individual samples are well below the predicted range. This may be due to overestimating the potential bacterial sources or underestimating the wet weather discharge of Centreville Creek into the Albion Hills beach.

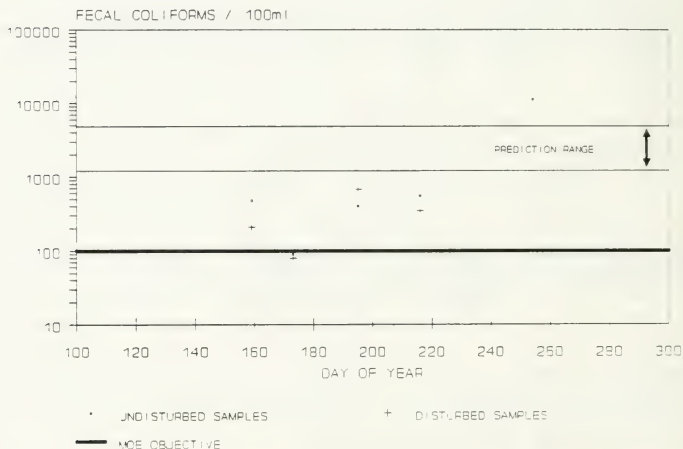


Figure 8: Wet weather - Predicted versus actual water quality at the Albion Hills Conservation Area beach. Water samples were collected under undisturbed and disturbed sediment conditions. 1986-89.

3.23 EAST HUMBER RIVER

The majority of bacteria delivered to the Boyd Conservation Area beach are from barnyard and inadequate manure storage runoff, and livestock access. Many farms are located in the Cold Creek subwatershed near the beach, less than 24 hours travel time (high flow) from Boyd (Table 3).

In figure 9, it is apparent that septic system failures and stormwater runoff produce large amounts of bacteria. However, bacteria from the towns of Oak Ridges, King City and Nobleton, on the upper East Humber River, are substantially reduced due to transport mortality by the time they contact the beach.

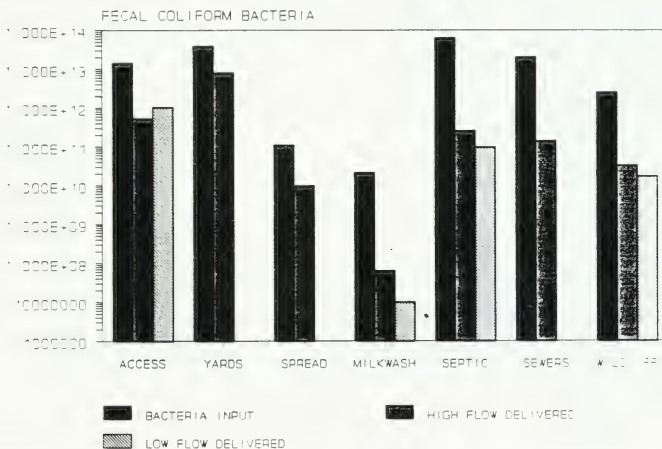


Figure 9: East Humber River - Bacteria source input versus bacteria delivered to the Boyd Conservation Area beach.

Summer dry weather model

The CURB model predicts livestock access to contribute 90% of the summer dry weather bacteria. This is followed by septic system failures at eight percent (8%) and wildlife at two percent (2%) (Table 3).

The high proportion of bacterial pollution from livestock access, is sourced primarily from farms within the Cold Creek subwatershed. The dry weather travel time is approximately 35 hours or one third to one fifth the travel time from the headwaters of the East Humber River.

In figure 10, the CURB model predicts a range of summer dry weather bacteria concentrations from 58 to 174 FC/100 ml. The field water sample geometric mean of 131 FC/100 ml collected at Rutherford road (undisturbed samples only), falls within the predicted range.

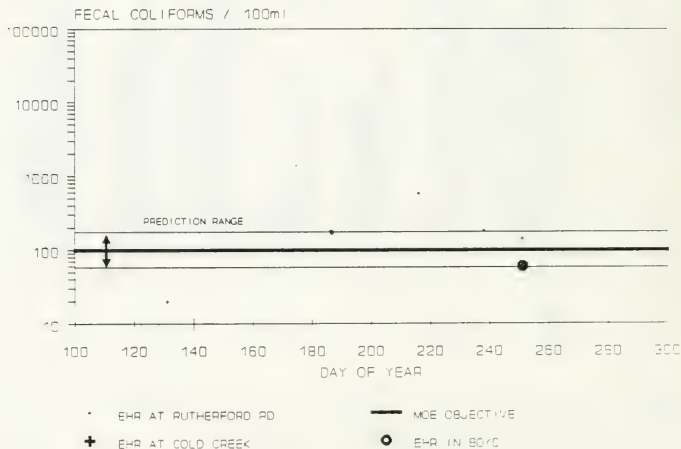


Figure 10: Dry weather - Predicted versus actual water quality at the Boyd Conservation Area. Water samples collected from 1986-89.

Summer wet weather model

In Table 3, the model predicts the agricultural contribution from barnyard and manure storage runoff to be 89% of the total wet weather bacterial contribution and livestock access falls to six percent (6%). Septic system failures contribute three percent (3%) and storm sewer runoff one percent (1%). Wildlife bacterial pollution decreases to less than one percent.

The wet weather CURB model predicts the beach concentrations between 801 and 2571 FC/100 ml. A relatively small number of field samples on East Humber River at Rutherford Road reveals a geometric mean bacteria concentration to be 942 FC/100 ml (figure 11).

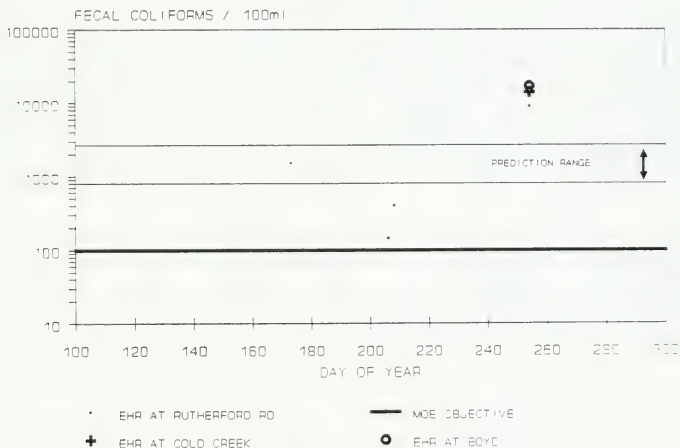


Figure 11: Wet weather - Predicted versus actual water quality at the Boyd Conservation Area. Water samples collected from 1986-89.

3.3 MODEL LIMITATIONS

The CURB prediction models do not account for bacterial deposition and resuspension. These are important factors that affect bacterial transportation in open water. The majority of bacterial pollution originates in wet weather (Table 3). These bacteria are deposited on streambeds, and are resuspended over time, creating beach impacts under dry weather conditions (M. Young, MOE. pers. comm.). This phenomenon is exhibited regularly on the Toronto waterfront beaches. Bacterial inputs from wet weather events are carried into near-shore areas, and may impair water quality for many days after their arrival.

For this reason it is imperative to control all dry and wet bacterial sources to maximize the prospect of measurable improvements to downstream water quality. Agricultural bacteria sources are primarily wet weather dependent. Barnyards and inadequate manure storages require rain to carry bacteria into watercourses. Thus, solving these problems may reduce wet weather bacterial input substantially, and improve dry and wet weather water quality.

4.0 CURB PLAN REMEDIAL OPTIONS

The CURB remedial options can be separated into three approaches (after Ryan, 1989);

1. Do nothing
2. Treat the symptoms of beach pollution
3. Control the pollution sources

4.1 OPTION 1

DO NOTHING

Permanent beach closures were the result of a failure to maintain acceptable water quality at the swimming beaches of the Claireville Conservation Area on the West Humber River, and the Boyd Conservation Area on the East Humber River. Although Claireville is not one of the Rural Beaches study areas, it is located close to Boyd, and is similar in both size and past popularity. Unfortunately, Claireville has also suffered permanent beach closures due to excessive bacterial contamination. For these reasons the effects of beach closures on Claireville are also examined.

It should be noted that the MTRCA, through its fisheries enhancement projects and sediment control programs, completed a number of remedial projects within both watersheds. However, the projects were not focused on improving swimming water quality. Consequently, changes in water quality at the swimming beaches were not investigated.

Costs of the 'Do Nothing' Approach

Without swimming beaches, the drawing power of the conservation areas diminished. Claireville and Boyd conservation areas

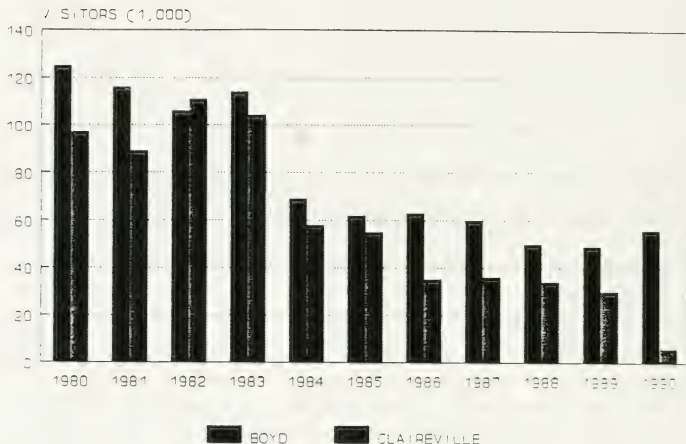


Figure 12: Annual summer attendance from June to August, 1980 to 1990, at Boyd and Claireville conservation areas. Beaches were permanently closed after the 1983 season.

suffered declines in visitor attendance since 1984 when the swimming beaches were permanently closed (Figure 12). Table 4 reveals average annual summer attendance reductions of 56,822 (49%) and 63,965 (64%) for Boyd and Claireville respectively. The subsequent decline in gate receipts and park attraction revenues, had forced the Authority to cease operations at the Claireville Conservation Area, in the Fall of 1990.

Other reasons may also have contributed to the decline in park popularity, these include: improved local recreational facilities of nearby suburban communities, and demographic changes. However, swimming is judged to be important by conservation areas guests. Visitor surveys (1989) revealed swimming to be the

single most important reason for visiting to Bruce's Mill and Albion Hills, and that it was an important form of summer recreation for over 60% of the respondents.

Expected Improvements from the 'Do Nothing' Approach

The 'do nothing' approach will have no impact on the status quo. Therefore, no water quality improvements are expected.

Table 4: Claireville and Boyd Conservation Areas - Average Summer Attendance 1980 -1990

	Claireville	Boyd
Average summer attendance 1980 - 1983 (Swimming beach open)	100,250	115,250
Average summer attendance 1984 - 1990 (swimming beach closed)	36,285	58,428
Percent decline after beach closures	- 64%	- 49%

Beaches were closed permanently in 1984.

4.2 OPTION 2

TREAT THE SYMPTOMS

The primary symptom of poor water quality at the study beaches, is bacterial densities that exceed the Provincial Water Quality Objective of 100 Fecal coliforms per 100 ml of water (MOE, 1987).

Chlorine disinfection of the Swimming Area

Artificial treatment of excessive bacterial concentrations in beach water is the most cost effective remedial approach, and ultimately the one chosen by the MTRCA. Beach chlorination

systems installed at Albion Hills (1986) and Bruce's Mill (1985) Conservation Areas, disinfects bacterially contaminated water. Except for occasional malfunctions, these systems have effectively reduced fecal coliform bacteria to almost zero (MOH, Peel and York).

Costs of Beach Water Treatment

The chlorination systems were installed at a cost of \$74,667 and \$68,609 at Albion Hills (1986) and Bruce's Mill (1985) respectively. The annual operating cost varies with the amount of chlorine and maintenance required during the season, generally falls between \$10,000 to \$15,000.

Chlorination has allowed these beaches to remain open in a semi-natural state. Aesthetically, visitors have complained about the "dirty" appearance of the water and the smell of chlorine. The vinyl curtain impounds chlorinated water in the beach area to maintain adequate residual chlorine levels, and to prevent downstream effects by the chlorine. However, it also contains sediment raised by swimmers. Safety problems may arise as reduced water clarity impairs lifeguards performance.

Expected Improvements from Beach Water Treatment

Semi-natural swimming has been available throughout the summer at both treated beaches since 1986. Figure 13 displays summer attendance at the Bruce's Mill and Albion Hills conservation areas, from 1980 to 1990. Although park attendance fluctuates, no obvious reductions occurred in 1984, the year Boyd and Claireville suffered visitor reductions of over 50%. Attendance was maintained after the chlorination systems were installed.

A 'net benefit' of at least \$137,000 per year is estimated for swimming at the Bruce's Mill and Albion Hills conservation areas.

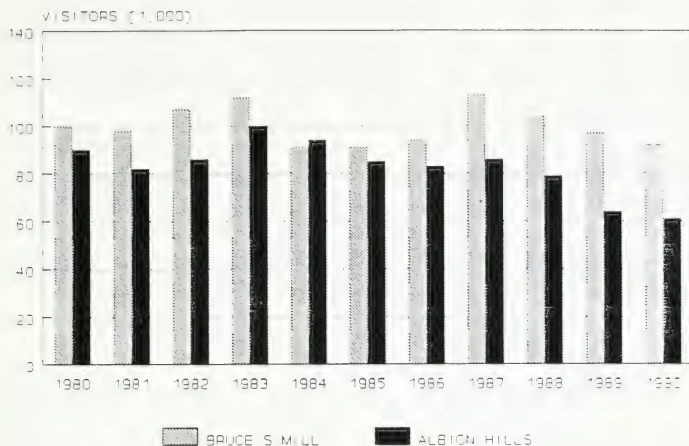


Figure 13: Annual summer attendance from June to August, 1980 to 1990, at Bruce's Mill and Albion Hills conservation areas. Chlorination systems began operation in 1985 and 1986 respectively.

Table 5: Bruce's Mill and Albion Hills Conservation Areas - Average Summer Attendance 1980 - 1990

	Bruce's Mill	Albion Hills
Average summer attendance 1980 - 1984	104,250	89,500
Average summer attendance 1985 - 1990	97,428	78,857
Percent decline	- 6%	- 12%

Chlorine disinfection systems were installed in 1985 and 1986, for Bruce's Mill and Albion Hills respectively.

This was calculated by extrapolating potential gate receipt losses, if swimming were cancelled at these beaches, and visitor attendance decreased by 50%. Spin-off income from food concessions and other park attractions were not included in the calculations.

This 'band-aid' solution to maintain swimming, has improvements limited only to the swimming beach. There are no benefits beyond the treated swimming areas since no other water quality improvements are achieved. Pollution sources continue to exist, and downstream impacts of degraded water quality remain.

4.3 OPTION 3

CONTROL THE POLLUTION SOURCES

Controlling pollution at its source is the most difficult and expensive strategy to return beaches to natural swimming. It requires a watershed approach to address individual problems that cause surface water contamination. The Rural Beaches Project has identified specific areas of concern through stream assessments, field surveys, and water quality monitoring. The CURB model consolidates this information to assist in developing a remedial action strategy that targets high priority sites.

4.31 Guide to Rural Land Use

All new or upgraded livestock facilities including buildings, barnyards, and manure storages, must adhere to design and site provisions in the Guide to Rural Land Use (OMAF and MOE, in progress). This document covers all aspects of environmental protection related to rural and agricultural land use.

Although the Guide to Rural Land Use strives to be comprehensive,

the following recommended remedial measures address specific concerns associated with management practices vital to protecting surface water quality.

Recommended remedial measures:

4.32 Improved manure management

Improved manure management can be divided into two categories:

- 1) To upgrade manure storage facilities and control barnyard runoff.
- 2) To improve manure handling practices.

The former is capital intensive, and latter is planning and labour intensive.

4.321 Improved facilities

Upgrade Manure Storages

Manure storages must contain all solid and liquid manure portions, and have a storage capacity of over 250 days. All storages must be absolutely water tight to prevent surface and ground water pollution. Covered storages are an alternative that prevents precipitation from being contaminated by manure. This eliminates the need to store and handle contaminated water.

Divert Runoff

Precipitation runoff should be diverted from being contaminated in barnyards and storages. Eavestroughs,

berms, and ditches are cost effective diversion techniques. Runoff that becomes contaminated must be captured and contained for proper field application.

These general measures serve three functions:

1. Total contaminated runoff is minimized, reducing the amount of liquid to be handled;
2. Complete manure containment prevents runoff into watercourses (the primary bacterial contaminant pathway in the target watersheds);
3. Increased manure storage capacity allows the farmer greater flexibility to apply manure when it is environmentally sound, and beneficial to crops (discussed below).

Minimum Separation Distances

New livestock buildings, barnyards, and manure storages must satisfy the above two criteria, and conform to a minimum separation distance of 150m to the nearest watercourse or municipal drain (Ryan, 1982). Existing barns that require expansion or upgraded storages, may be exempt due relocation difficulties.

Robinson and Draper (1979) determined 122m to be the optimal distance for attenuation of phosphorus in surface runoff. However, field observations have occasionally uncovered runoff conditions in excess of 150m (D. Hayman pers comm, 1987). New municipal zoning bylaws that incorporate a minimum separation distance of 150m, can reduce or eliminate potential contaminated runoff problems from new facilities.

4.322 Improved management practices

There is plethora of information available on the subject from OMAF, agricultural groups, and independent research studies. A thorough investigation into proper manure management is beyond the scope of this report. It is suggested that research begin with OMAF Publication 296 - 1988 Field Crop Recommendations (1987).

Farms with inadequately sized storages, may be forced to spread manure during less than optimum periods. If adequate manure storage facilities exist, operators can practice improved manure application rates, timing, and methods.

Manure Application Rates

Manure application rates can be determined by evaluating the field conditions, soil type, crop needs, and existing soil nutrients. Soil and manure testing is required, and manure spreader calibration will ensure correct nutrient application.

Timing of Manure Application

Timing when manure is applied is important to maximize nutrient benefits and prevent runoff into watercourses. Manure spreading on frozen or saturated ground is no longer acceptable. Substantial runoff can occur during thaws or heavy rains, posing a serious environmental hazard. Volatilization losses from exposed manure significantly reduces nitrogen availability to crops.

Methods of Manure Application

A contingency plan should be prepared for potential manure spills.

Manure should be applied to minimize runoff. On hay and pasture, manure should be applied at least 5m from a watercourse. Solid manure spreading on worked fields must be incorporated into soils within 24 hours to prevent potential wash-off by precipitation, and nitrogen losses to the atmosphere.

Liquid manure application should be calibrated to prevent any surface runoff. Injection and banding (injection into seedbed rows) are the best alternatives. Liquid manure applied to tile drained fields requires monitoring of tile outlets to ensure no manure escapes into drains or watercourses.

Improved manure management practices requires greater farmer awareness. To plan a manure storage and handling system, or determine how, when, and where manure can be best applied, may be viewed as too time consuming. However, education should be aimed at changing perceptions of manure from a disposal problem to a resource. Significant on farm benefits can be realized if manure is utilized as such.

4.33 Restricted livestock access to watercourses

Livestock must be fenced out of watercourses. Cattle that water from a stream will require alternate watering devices such as nose pumps, electric or solar powered pumps. Livestock crossings through watercourses must be restricted to reduce contact with water. High level (culvert) crossings are preferred to stream level crossings.

Livestock have traditionally been pastured in bottom lands. Cattle watering from streams is still a common practice in the MTRCA watershed. However, serious environmental degradation can result from livestock access to watercourses:

1. Livestock manuring in or near a watercourse will cause bacterial contamination that can impair downstream recreational water use, and may spread diseases to livestock or wildlife. Nutrient loads will create excessive algal growth leading to eutrophication.
2. Livestock trampling causes streambank erosion, and streambed destruction. Increased sediment loads can smother fish gills, and spawning sites. Bacterial and nutrient contaminants are attached to sediment particles, and can be carried and released downstream, creating problems indicated above.

4.34 Milkhouse washwater treatment or containment

Milkhouse washwater drains from an average dairy herd, can discharge an average of 35 kg of phosphorus per year into watercourses. Milk solids flushed from the pipeline rinse cycle provide a growth media for bacteria. Consequently bacterial concentrations have been found to exceed the objective of 100 FC / 100ml by over 100 times (Hayman, 1988).

Milkhouse washwater must be:

1. Treated in an OMAF approved tank and treatment trench system, or;
2. Directed to a liquid manure storage for future land application.

A recent innovation uses hydrogen peroxide and cider vinegar in place of phosphate detergents for dairy pipeline cleaning (Samson, 1990). The attributes are impressive: it is phosphate free, the hydrogen peroxide is bactericidal, and the cost is lower than commercial detergents. If long term feasibility can be achieved, this method can reduce the economic and environmental impact of milkhouse washwater disposal.

4.35 Repairing or replacing faulty septic systems

Private sewage systems are designed to safely dispose of domestic waste and washwater. Faulty septic systems can cause serious health hazards, and impair surface or ground water.

Faulty systems must be repaired or replaced. All household waste and washwater must be directed to the septic systems. Grey water must not be connected to field tile. Septic tanks should be pumped out at least once every three years.

4.36 Municipal Sewage Treatment

Existing and proposed municipal sewage treatment projects within the study watersheds are presented here because of their possible improvement to local water quality. These independent municipal projects are unrelated to the Rural Beaches Project. This report will not comment on the feasibility or cost effectiveness of municipal sewage treatment to rectify environmental impacts from faulty private sewage systems.

Three communities within the study watersheds have decided to replace private sewage systems with municipal sewage collection and treatment. This may resolve the issue of faulty septic system impacts on watercourses from those communities. However,

contaminants in suburban stormwater runoff, including nutrients and bacteria from lawn fertilizers, pesticides, wildlife droppings, and pets, will continue to enter watercourses (Pitt, 1982). The costs of connecting homes to the service lines are borne by the homeowners.

Oak Ridges

The community of Oak Ridges is presently converting from private sewage systems to municipal sewage treatment. The Town of Richmond Hill in July, 1990, passed a municipal bylaw requiring all homes, in the community of Oak Ridges (headwater of the East Humber River), to be connected to the municipal sewage lines. As of December, 1990, 68% of all homes have been connected. All sewage will be collected and directed to the York Durham Waste Water Scheme (P. Horvath, Water and Sewer Technician, Town of Richmond Hill. pers. comm. 1990).

Caledon East

The community of Caledon East (Centreville Creek) intends to undertake a similar strategy. The Regional Municipality of Peel has completed an environmental study report for the proposed conventional sewage collection system that will direct sewage from Caledon East into the existing municipal sewer within the City of Brampton for treatment in the South Peel Sewage Treatment Plant (John Hook, Director of Engineering, Town of Caledon. pers. comm. 1991).

Although Caledon East is located on Centreville Creek, it has demonstrated only local water quality impairment from evidence of sewage effluent in stormsewer runoff. Stream water quality improvement may result from municipal sewage collection. However, it may not influence water quality downstream of Innis Lake, or affect the swimming beach at the Albion Hills Conservation Area. (See section 3.22, Centreville Creek summer wet weather model).

Kleinburg

A proposed bylaw will be brought before the Town of Vaughan council in the summer 1991, requiring all homes to connect into municipal sewage lines in the community of Kleinburg (East Humber River). Servicing will replace all private sewage systems presently operating in Kleinburg, north of Stegman's Mill Road, including Main and Centre Streets. All sewage will be directed to the upgraded York Region Sewage Plant located near the main Humber River.

No systematic evaluation was conducted by the Authority on the water quality impact of any faulty septic systems on the East Humber River or the Boyd conservation area beach. However, the age of some septic systems, and their questionable year-round effectiveness, were concerns that led to the servicing of the community (Clark Campbell, Deputy Director of Public Works, Town of Vaughan. pers. comm. 1991).

4.37 Waterfowl control program

An effective goose control program will reduce the impact of bacterial pollution at the beach sites. Staff will:

1. Manipulate goose eggs during the spring nesting season.
2. Transfer geese to other Authority properties during their moult in early summer.
3. Manage transient geese during the swimming season, using various harassment techniques including, bird scarring cannons, and pistol launched noise crackers.

4.4 CAPITAL COST TO CONTROL POLLUTION SOURCES

4.41 Initial and long term costs

The predicted cost for remedial measures can be divided into two groups: the initial project capital cost, and the long term cost of management and maintenance. The former would include the construction of manure storage facilities, livestock fencing and alternate watering devices, and new or upgraded septic systems. The latter relates to improved management practices such as the handling methods for manure or the rotation of livestock on pastures restricted from watercourses. Regular maintenance of fencing and septic systems are also long term costs.

The estimated CURB costs will include only the initial capital construction costs. It is assumed that operating and maintenance expenses will be sustained by the individuals concerned. The waterfowl control program and other beach management techniques will be incorporated into conservation area operating costs. Costs for information and education will be included as part of the program delivery.

4.42 Capital Costs for Remedial Measures

Capital costs to implement remedial measures in the Bruce Creek, Centreville Creek, and East Humber River watersheds are displayed in Table 6. The number of sites do not correlate with the number of livestock operations. Farms may require more than one remedial measure, such as restricted cattle access and an upgraded manure storage.

The costs were calculated from preliminary individual farm remedial action plans, designed for each high priority livestock operation (Appendices 1 to 4). The cost estimates are based upon

the values from the MOE CURB Workshop (Kempenfelt 1987). Some changes were made to reflect a higher cost of labour and materials in the greater Toronto area.

Cost estimates for the construction of concrete structures were multiplied by two. Estimates for manure storages, barnyards and retaining walls are double the suggested costs. This change due to the construction cost of a liquid manure storage at the Albion Hills Demonstration Farm, which was approximately twice the price based on the Workshop (Kempenfelt 1987) values.

The septic system costs are based on a \$10,000 price of newly installed systems in York Region. No septic system costs were included for the community of Oak Ridges.

4.43 Expected Improvements from Controlling Pollution Sources

Within the scope of this study, it is difficult to quantify downstream water quality improvements made by upstream remedial measures. A qualitative analysis will outline some of the expected improvements from controlling pollution sources.

Beach Improvements

The primary objective of the Rural Beaches Project is to implement remedial measures on pollution sources that contaminate downstream swimming beaches. Rectifying upstream bacterial sources may translate to a decrease in bacterial concentrations at the conservation area swimming beaches, and a subsequent reduction in beach closures. Without relying on the chlorine disinfection systems, between \$10,000 and \$15,000 in operating and maintenance costs can be saved annually.

Table 6: Estimated capital costs of remedial measures to reduce bacterial inputs upstream of the swimming beaches at Bruce's Mill, Albion Hills, and Boyd Conservation Areas.

Watershed	Number of sites	Estimated Capital Construction Cost
Bruce Creek		
Livestock access	4	\$16,000
Barnyards and storages	2	74,000
Milkhouse washwater	-	-
Septic system failures	3	30,000
	-----	-----
Total projects	9	\$120,000
Centreville Creek		
Livestock access	7	\$ 19,000
Barnyards and storages	9	512,000
Milkhouse washwater	1	5,000
Septic system failures	5	50,000
	-----	-----
Total projects	22	\$ 586,000
East Humber River		
Livestock access	20	\$ 115,000
Barnyards and storages	19	1,407,000
Milkhouse washwater	3	15,000
Septic system failures ¹	114	1,140,000
	-----	-----
Total projects	156	\$ 2,677,000

1 The total number of septic system projects do not include homes in the community of Oak Ridges. Due to a recent municipal bylaw, all homes are required to connect into sanitary sewers by 1992. Thus, no costs are predicted for septic system repairs or upgrades.

General water quality improvements

The treatment of bacterial runoff sources will reduce associated phosphorus and nitrate loads. Reduced nutrient runoff may decrease nuisance algal growth, and improve watercourse aesthetics. Eliminating cattle access to watercourses reduces streambank erosion, streambed trampling, and sediment loading. With less soil entering watercourses, stream habitat may improve and drain clean-out costs may be reduced. Without manure input to a watercourse, less nuisance algal growth will result, and the biochemical oxygen demand (BOD) may be reduced. This may improve local dissolved oxygen levels, and would enhance aquatic habitat suitability. The overall result is improved fish species diversity and quantity that may contribute to greater angling opportunities for sport fishermen.

Properly functioning septic systems can reduce health risks to the residents, prevent odours, and eliminate wet spots over tile beds.

Agricultural Improvements

With expanded manure storage facilities, optimal timing of manure application can be realized. This would maximize nutrient availability for crops and minimize environmentally hazardous runoff into surface waters or leaching into groundwater.

Improved manure management practices that reduces runoff to watercourses will have on farm benefits as well. Proper manure application will increase soil fertility, reduce the amount of synthetic fertilizers required, improve soil texture, enrich organic matter content, and provide soil micronutrients.

A dairy operation can realize substantial benefits from improved manure management practices. Properly timed field applications of solid manure at 10 tonnes/ha can provide NPK equivalents of 30-10-44 kg/ha (OMAF, 1987). Each dairy cow can provide between \$40 and \$60 of nutrient value per year (Table 7). This can offset the cost of manure spreading and commercial fertilizers.

TABLE 7: Value of Manure Nutrients

Nutrient	Kg/Cow	% Availability	Value in Dollars
N	77	25 - 60	10 - 25
P	36	40	10 - 12
K	81	90	20 - 24

From: Farm & Country, pg 55, April 24, 1990.

Without livestock standing in watercourses or drinking contaminated water, herd health improves and livestock operators may realize reduced veterinary costs. Removing dairy cattle from watercourses may reduce the incidence of mastitis. Numerous disease causing pathogens can be transmitted in water such as: E. coli, Salmonella, Leptospira, Bacillus anthracis (foot and mouth disease virus), and enteroviruses. Local wildlife can benefit by reducing their chances of contracting barnyard diseases from contaminated streams.

5.0 CURB PLAN STRATEGY

IMPLEMENT REMEDIAL MEASURES ON ALL POLLUTION SOURCES

In an effort to improve water quality at the conservation area swimming beaches, the CURB plan recommends that all pollution sources be systematically addressed. Partial treatment may not achieve significant improvements.

In this section, the CURB model will estimate water quality changes when hypothetical combinations of remedial measures are implemented. The model predictions will provide a guide to the effectiveness of various remedial measures. Consult section 3.3 Model Limitations for potential problems associated with the predictions.

The Watershed Approach

The most efficient use of limited resources would be to target efforts on a watershed basis. The recommended objective is to implement remedial measures on all pollution sources, beginning with the Bruce Creek watershed to return the Bruce's Mill Conservation Area beach to natural swimming. As a pilot project, its success can be evaluated prior to extensive implementation in the other two watersheds.

Bruce Creek

Being the smallest of the three study watersheds, it has the fewest number of problem sources, and is the least costly to correct (Table 6).

Rectifying all agricultural bacteria sources and rural septic system failures, at an estimated cost of \$120,000, may reduce an estimated 84% of the total summer bacterial impacts to the beach (Table 3).

Wildlife accounts for only six percent (6%) of the bacterial impact. Approximately half of this (3%) are estimated to originate from the 20 to 40 geese at the beach area.

Applying the CURB model to predict the effects of remedial measures on beach water quality (Figure 14), reveals limited water quality improvements in dry weather for individual remedial measures except septic systems. When repairing septic systems alone, the model estimates low flow bacterial densities slightly below the objective of 100 FC/100ml. The treatment of all agricultural sources (87%) may provide the most effective beach water quality improvement. When further improvements are made to septic systems, and geese at the beach are removed, the resultant predicted water quality is well below 100 FC/100ml (Figure 15). Reducing inputs from the latter sources alone may reduce bacterial sources by nine percent and is estimated to achieve only minor water quality improvements (Figure 14).

Thus, it is recommended that all bacteria sources be addressed in an attempt to improve recreational water quality at the Bruce's Mill Conservation Area.

Centreville Creek

The Centreville Creek watershed is the second watershed suggested for systematic reduction of all bacterial sources. It is a larger watershed with over twice the number of identified pollution sources (Table 6).

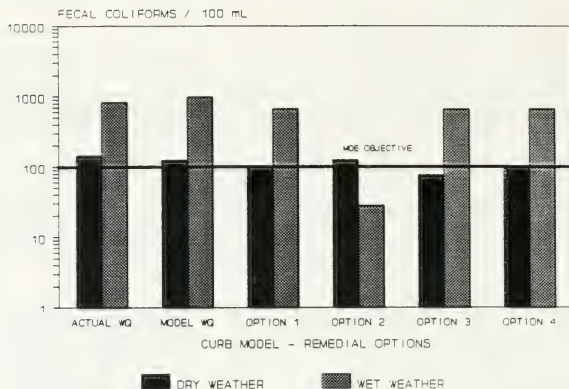


Figure 14: Bruce's Mill Conservation Area - Beach water quality predictions for individual remedial options.

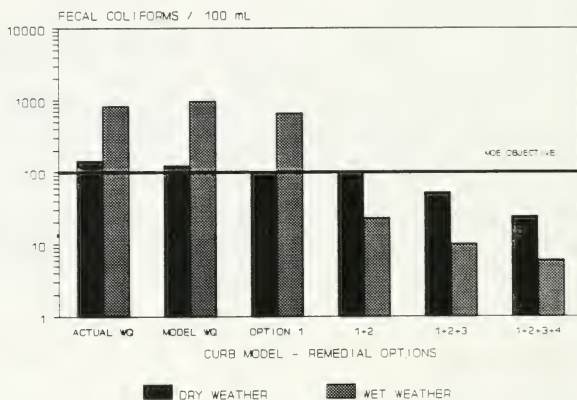


Figure 15: Bruce's Mill Conservation Area - Beach water quality predictions for combined remedial options.

Remedial Options: 1. No Livestock Access 2. No Barnyard Runoff
 3. No Septic System Failures 4. No Waterfowl on Beach

An estimated 94% of the summer bacterial sources can be eliminated for an estimated \$586,000 in the Centreville Creek watershed. Most of the cost is for improvements or construction of new barnyards and manure storages (\$512,000). The estimated summer bacterial reduction from this source alone will be 87%.

The Curb model (Figures 16) shows that treating individual sources will have small effects on water quality in dry weather, and almost no effect in wet weather. The estimated improvement to water quality is largest in wet weather when bacteria from barnyard and manure storage runoff are controlled (Figure 17). Controlling all bacterial sources is estimated to achieve beach water quality below 100 FC/100ml in dry and wet weather conditions.

East Humber River

Because of its size, and the complexity of bacterial sources, the achievement of measurably improved water quality in the East Humber River watershed will be difficult. It is recommended that remedial measures for be directed to the part of this watershed closest to the beach where potential improvements are high.

Restricting livestock access may reduce 16% of the summer bacterial load to the beach, at a cost of \$115,000. This is the most cost effective remedial measure in this watershed. The CURB model predicts dry weather water quality to be less than 10 FC/100ml (figure 18). Barnyards and manure storage runoff constitute 79% of the summer bacteria load to the beach, and can be eliminated for \$1,407,000. The majority of livestock operations that impact the Boyd Conservation Area beach, are located nearby in the Cold Creek watershed, which occupies the lower quarter of the East Humber River watershed.

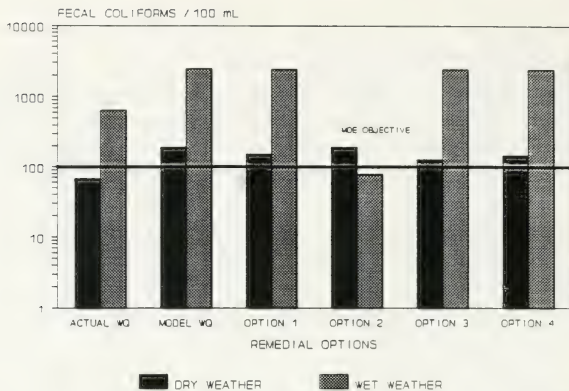


Figure 16: Albion Hills Conservation Area - Beach water quality predictions for individual remedial options.

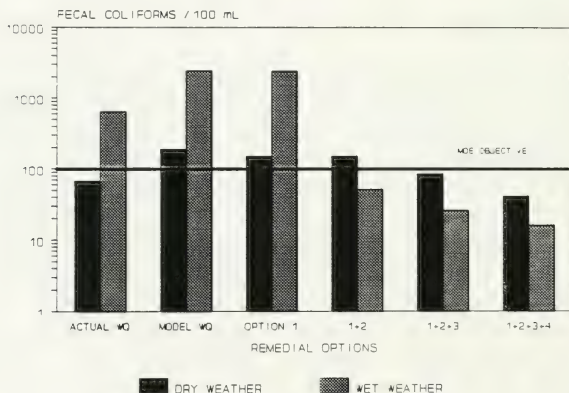


Figure 17: Albion Hills Conservation Area - Beach water quality predictions for combined remedial options.

Remedial Options: 1. No Livestock Access 2. No Barnyard Runoff
3. No Septic System Failures 4. No Waterfowl on Beach

Bacterial contamination from suburban septic systems and storm sewer discharge in the upper East Humber River, have been documented to significantly impair local water quality (Hubbard et. al. 1988). However, treatment is limited to septic systems only, reducing beach bacterial loads by only 3% at a cost of \$1,140,000. The modelled water quality show little change when only faulty septic systems are addressed (Figure 18). Methods and costs of improving suburban storm water quality have not been evaluated in this report.

In Figure 19, modelled water quality based upon full treatment of all sources reveals dry and wet weather bacterial densities to be under 20 FC/100ml. These are rather optimistic CURB model estimates. No attempt was made to estimate the potential geese populations. The Boyd beach has not been open since 1984 and no swimming area exists for the geese to inhabit.

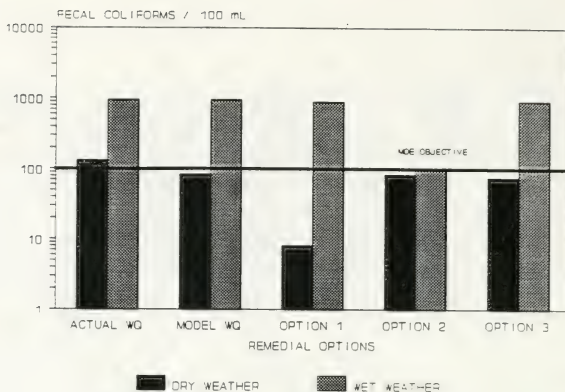


Figure 18: Boyd Conservation Area - Beach water quality predictions for individual remedial options.

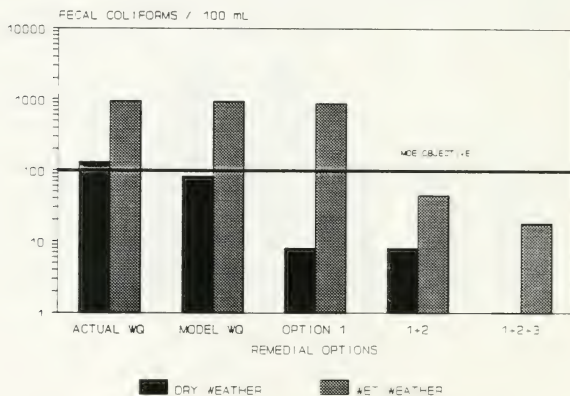


Figure 19: Boyd Conservation Area - Beach water quality predictions for combined remedial options.

Remedial Options: 1. No Livestock Access 2. No Barnyard Runoff
3. No Septic System Failures 4. No Waterfowl on Beach

8.0 CURB IMPLEMENTATION PLAN

Water quality monitoring, field assessments, and the CURB model have shown that considerable water quality degradation results from inadequate land management practices. Although agricultural programs have been available in the past to deal with some of these problems, participation has been strictly voluntary with limited emphasis on specific areas of concern. In order to effect water quality improvements throughout the watershed, the program must be watershed based. A proactive approach is required to promote the principal remedial efforts of: adopting improved manure storage and management practices, livestock access restriction, and repairs to faulty septic systems.

The Ministry of the Environment is requested to fund the CURB implementation program. The program would be administered by the MTRCA, within the framework of the Rural Beaches Project, and under the direction of the multi-agency steering committee. Two full time positions, and associated support costs, are recommended. Laboratory services should continue to provide adequate support to further investigate contaminant sources and to monitor the effectiveness of remedial measures. The time period for the program should be 5 years, or at least as long as the financial assistance program indicated below.

6.1 PROGRAM DELIVERY

Working with the rural community will require cooperation from government agencies and rural organizations that share a common interest in resource management. The MOE should be the lead agency since its mandate is the protection of the province's water resources. The Ontario Ministry of Agriculture and Food, as well as agricultural organizations including the local Ontario

Soil and Crop Improvement Association (OSCIA), and the local Federation of Agriculture (OFA), can provide guidance to implement environmentally compatible management practices. The local public health office can be utilized to address bacterial sources related to private sewage systems in rural and suburban areas. The Authority can deliver program components on a local watershed basis.

To effect changes to present methods of rural land use necessitates the implementation plan to focus on three areas; problem awareness, technical assistance and financial assistance.

6.11 Problem Awareness

An effective CURB strategy must include a broad based education program to increase public awareness of rural pollution sources. The (CURB) Plan has identified agriculture as a significant contributor to bacterial pollution in the target study areas. If not properly managed, nutrients, soil, manure and chemicals associated with agricultural practices can have negative environmental impacts on surface water quality.

It is imperative that farmers, rural residents and the general public understand the link between agricultural activities, rural urban land use, and water quality. The Authority would deliver an information and education campaign to increase awareness of water quality issues, and propose the best methods and management practices for achieving and maintaining improved water quality.

6.12 Technical Assistance

Agricultural water quality management plans

Preliminary farm abatement (CURB) plans have been drafted, for high priority farms, that address on-farm sources of bacterial loading into surface waters. These plans will act as planning tools for individual farm operators to prioritize specific problems, and make management decisions based upon economic and environmental concerns.

Although individual CURB plans are based on technical abatement measures, sound management practices are essential for the successful reduction of pollution problems. Assistance from OMAF field staff and the local OSCIA and OFA is required to ensure improvements under varying physical conditions on each farm.

6.13 Financial Assistance

Coupled with educational efforts and technical assistance, there should be a greatly expanded program of financial assistance to encourage land managers to develop and implement their comprehensive water quality management plans. To effect progress towards reducing agriculturally related water quality problems, public funds are required to offset the cost of capital intensive projects.

Previous assistance programs were considered inadequate by some farm operators. The Ontario Soil Conservation and Environmental Protection Assistance Program (OSCEPAP II) provided a 40% grant rate with a \$7,500 ceiling, for environmental protection projects. However, a new manure storage and liquid runoff tank, for an average dairy herd of 35 cows, may cost approximately \$30,000. The low maximum grant (\$7,500) may have required some

design compromises to reduce costs. However, environmental benefits may also have been reduced.

A financial assistance program should provide a grant rate between 75% and 90% of the total capital costs for agricultural remedial measures. In the United States, the experimental Rural Clean Water Program successfully used a grant rate of 75% to encourage the implementation of capital intensive projects. The York Federation of Agriculture suggested that a 90% grant rate is required for participation by farms located within the urban shadow of the greater Toronto area. The grant ceilings should depend on the remedial options adopted. Ceilings that are too low can deter the construction of environmentally friendly systems.

A proposed 90% grant rate is much higher than previous grant assistance programs and may be justified on two counts. Firstly, it removes financial impediments posed by the inadequacy of previous assistance programs. Secondly, this rate clearly indicates the degree of importance being placed on correcting existing problems.

It seems reasonable, however, that a specific time limit be placed on the availability of this grant; perhaps for a period of five years. During this period, every effort should be made to encourage uptake. As a last resort, the prospect of abatement would exist at the end of the five years.

7.0 REFERENCES

Bones, H., 1990. Supervisor Public Health Inspection. York Region Public Health Department. Personal Communication. Newmarket, Ontario.

Campbell, C., 1991. Deputy Director of Public Works, Town of Vaughan. Personal Communication. Maple, Ontario.

Ecologistics Limited, 1988. PLOP - A Planning Tool to Evaluate the Pollution Potential of Livestock Operations in Southern Ontario. Waterloo, Ontario.

Fuller, R. and M.E. Foran, 1989. Clean Up Rural Beaches (CURB) Plan for Lake Huron Beaches in the Maitland Valley Conservation Authority Watershed. Wroxeter, Ontario.

Hayman, D.G., 1989. A Clean Up Rural Beaches (CURB) Plan for Fanshawe, Pittcock and Wildwood Reservoirs in the Upper Thames River Conservation Authority. London, Ontario.

Hayman, D.G., 1988. Subsurface contamination with Milkhouse Wastewater - An Environmental Concern, Upper Thames River Conservation Authority. London, Ontario.

Hayman, D.G., 1987. Rural Water Quality Program Coordinator, Upper Thames River Conservation Authority. Personal Communication. London, Ontario.

Hocking, D. and D. Dean, 1989. Ausauble Bayfield Conservation Authority Target Sub-basin Study Report. Exeter, Ontario.

Hook, J., 1991. Director of Engineering, Town of Caledon. Personal Communication. Caledon East, Ontario.

Horvath, P., 1990. Water and Sewer Technician, Richmond Hill Works Department. Personal Communication. Richmond Hill, Ontario

Hubbard, R., B. Hindley, H. Power, and P. Mar, 1987. Metropolitan Toronto and Region Conservation Authority, Rural Beaches Impact Study 1986. Downsview, Ontario

Hubbard, R., P. Mar, H. Power, and T. Ryan, 1988. Metropolitan Toronto and Region Conservation Authority, Rural Beaches Impact Study 1987-88. Downsview, Ontario.

Little, C.E., 1989. The Rural Clean Water Program: A Report. U.S. Department of Agriculture. Kensington, Maryland.

Marsalek, J., V. Panu, and H.Y.F. Ng, 1985. Storm Runoff Study of the Newton Urban Catchment. Urban Hydrology Study of the Waterford River Basin, Technical Report No. VHS WRB 1.5. Environment Canada.

Metropolitan Toronto and Region Conservation Authority., 1990. Conservation Area Visitor Survey Results, June 1 to September 4, 1989. Downsview, Ontario.

Ontario Ministry of Agriculture and Food, 1987. Publication 296, 1988 Field Crop Recommendations. ISSN 0701-5321. Ontario.

Ontario Ministry of the Environment. 1984. Water Management - Goals, Policies Objectives and Implementation Procedures of the Ministry of the Environment. Toronto, Ontario.

Palmateer, G., 1990. Microbiologist. Ministry of the Environment. Personal Communication. London, Ontario.

Pitt, R., 1982. Urban bacteria sources and control by street cleaning in the Lower Rideau River watershed. Ottawa, Ontario.

Robinson, J.B. and D.W. Draper, 1978. A Model for Estimating Inputs to the Great Lakes from Livestock Enterprises in the Great Lakes Basin; Report to Pollution from Landuse Activities Reference Group, Task C, Agricultural watershed studies, I.J.C., Windsor, Ontario.

Rowney, A.C. and P.E. Wisner, 1986. Qualhymo, User Manual Release 1.1. Queens University, Kinston. University of Ottawa.

Ryan, T.E., 1982. Assessment of Potential Water Quality Problems from Agricultural Manure Handling and Storage Systems. Ausable Bayfield Conservation Authority. Exeter, Ontario.

Ryan, T.E., 1989. The Grand River Rural Beaches Study, Clean Up Rural Beaches (CURB) Plan. Cambridge, Ontario.

Samson, R., 1990. Taking the P out of Your Washwater. Sustainable Farming, Vol. 1, No. 3. Ste. Anne de Bellevue, Quebec.

Thelin, R. and G.F. Gifford, 1983. Fecal Coliform Release Patterns from Fecal Material of Cattle. Journal of Environmental Quality, Volume 12, No. 1.

Toombs, M. 1990. Agricultural Engineer. Ontario Ministry of Agriculture and Food. Personal communication. Newmarket, Ontario.

Young, M. 1990. Microbiologist. Ministry of the Environment. Personal Communication. Rexdale, Ontario.

APPENDIX 1

Clean Up Rural Beaches (CURB) Model

POLLUTION FROM LIVESTOCK OPERATIONS PREDICTOR (PLOP) MODEL

The PLOP model (Ecologistics, 1988) calculated farm bacterial contamination for these individual sources:

Livestock access (ACCESS),
Barnyard and manure stack runoff (BARNYARD AND STACKS),
Milkhouse washwater discharge (MILKHOUSE)

BACTERIAL TRANSPORT MODEL

Each bacterial output from the PLOP model is mathematically transported to the beach with the MTRCA CURB transport model. The bacterial travel time is calculated for each individual farm under dry and wet weather conditions. The presented results predicts, for each source, the load of fecal coliform bacteria to the beach.

ACCESS

The PLOP model estimates bacterial pollution to be 3.84×10^{10} fecal coliforms / kg of manure (after Crane et. al., 1983). This is 43 times higher than the 8.9×10^5 fecal coliforms / kg obtained from local samples (M. Young, MOE, pers. comm.). It is assumed the PLOP model overestimates livestock access bacterial pollution. Thus, the PLOP model livestock access predictions are divided by 43, prior to transportation by the CURB model.

ACCESS L: (PLOP MODEL SUMMER LIVESTOCK ACCESS FECAL COLIFORM BACTERIA LOAD / 43 / 92 DAYS) X 79 DAYS - (LOW FLOW TRAVEL TIME X DISAPPEARANCE RATE)

= Beach bacterial load for each source at low flow (79 days)

FCBEACH H: (PLOP MODEL SUMMER LIVESTOCK ACCESS FECAL COLIFORM BACTERIA LOAD / 43 / 92 DAYS) X 13 DAYS - (HIGH FLOW TRAVEL TIME X DISAPPEARANCE RATE)

= Beach bacterial load for each source at high flow (13 days)

CURB COST: Cost for 100% livestock restriction from watercourses and all necessary ancillaries, which may include: fencing, low level crossings and alternate watering devices.

BARNYARD AND MANURE STACK

All bacterial runoff from barnyards and manure stacks were assumed to be due to wet weather events. Therefore 100% of the PLOP model outputs were calculated as a high flow (wet weather) contaminant source.

BARN HI: (PLOP MODEL SUMMER BARNYARD AND MANURE STACK FECAL COLIFORM BACTERIA LOAD) - (HIGH FLOW TRAVEL TIME X DISAPPEARANCE RATE)

= Beach bacterial load for each source at high flow (13 days)

CURB COST: Cost to eliminate all manure contaminated runoff from existing barnyards and manure storages. This is based on double the cost of OMAF estimates from the MOE Kempenfelt workshop. At the MTRCA's Albion Hills Farm, the cost to construct a new manure storage was almost twice the estimated OMAF values.

MILKHOUSE

Bacterial contamination from improper milkhouse washwater effluent treatment.

MILK LO: (PLOP MODEL MILKHOUSE WASHWATER FECAL COLIFORM BACTERIA LOAD / 43 / 92 DAYS) X 79 DAYS - (LOW FLOW TRAVEL TIME X DISAPPEARANCE RATE)

= Beach bacterial load for each source at low flow (79 days)

MILK HI: (PLOP MODEL MILKHOUSE WASHWATER FECAL COLIFORM BACTERIA LOAD / 43 / 92 DAYS) X 13 DAYS - (HIGH FLOW TRAVEL TIME X DISAPPEARANCE RATE)

= Beach bacterial load for each source at high flow (13 days)

CURB COST: \$5,000 is the estimated cost to construct a new approved milkhouse tank and treatment trench system. This is based on a an average sized dairy farm in the study watersheds.

MANURE SPREADING BACTERIA RUNOFF MODEL

SEASON:	Based on Plop model seasons (Ecologistics, 1988) Spring = March 15 - June 14, Summer = June 15 - September 14, Fall = September 15 - December 14, Winter = December 15 - March 14
VOM KG:	Volume of estimated manure production in the watershed (after MOE Kempenfelt conference, 1987)
EAU:	Estimated number of animal units in the watershed (Ecologistics, 1988).
FC/KG:	Estimated fecal coliform load per kg of manure (after MOE Kempenfelt conference, 1987).
% of MANURE SPREAD:	Seasonal fraction of manure field application over a period of one year. Assuming annual production equals annual spreading (Michael Toombs, OMAF, pers. comm.). Spring = 45 %, Summer = 20 %, Fall = 30 %, Winter = 5 %
FARMS WINTER SPREAD:	The fraction of farmers spreading manure in a given season. Value of 1 means 100% for all seasons except winter. Survey results from the three study watersheds indicates 57 % of farmers spread manure in the winter (Hubbard et. al., 1988).
% OVERSPREAD:	Number of farmers that over-spread manure. This is assumed to be 5 % for spring through fall, and 100% for winter manure spreaders (after Hayman, 1989).
AMOUNT OVERSPREAD:	Estimated manure over-spread by applicators that over-spread manure. This is assumed to be 25 % for spring through fall (Thelin and Gifford, 1983), and 100% for winter manure spreaders (after Hayman, 1989).
DELIVERY RATIO:	The estimated amount of bacteria from manure over-spreading that enters a watercourse (1%)
STORAGE	
SURVIVAL DAYS:	Estimated manure storage time (25 days) before each cleanout for field application (Ecologistics, 1988., Thelin and Gifford, 1983)
T + G 83 10 + 15 RATE:	Bacteria survival rates based on Thelin and Gifford's (1983) 10 + 15 day rate, multiplied by STORAGE SURVIVAL DAYS = 0.01 log units
FIELD SURVIVAL DAYS:	7 days is the estimated in field time before each rainfall generates enough runoff to enter a watercourse.
T + G 83 10 + 15 RATE:	Bacteria survival rates based on Thelin and Gifford's (1983) 10 + 15 day rate, multiplied by FIELD SURVIVAL DAYS = 0.275 logs
TOTAL SURVIVAL RATE:	Combined bacteria survival rate. 0.01 logs x 0.275 logs = .0037 logs
TOTAL MANURE RUNOFF:	Total seasonal fecal coliform bacteria runoff = VOM KG x FC/KG x % OF MANURE SPREAD x FARMS WINTER SPREAD x % OVERSPREAD x DELIVERY RATIO x TOTAL SURVIVAL RATE

BACTERIAL TRANSPORT MODEL

This model calculates the bacterial disappearance in transportation from the source input location to the beach for the following sources:

SEPTIC:	Failed septic systems	(Bacteria for this source was not transported. It was assumed that 5% of geese fecal coliform bacterial production directly entered the beach water. See Appendix 5)
WILDLIFE:	Instream beaver and muskrat	
GEESE:	Canada Geese on or near the beach area	
SPREADING:	Manure spread on farm fields	
STORM WATER:	Stormwater runoff (in East Humber River watershed only)	

FC (source): Estimated fecal coliform bacteria generated for each source over 92 days.

TIME IN HOURS: Low and high flow travel time, in hours, from the midpoint of the watershed to the beach.

FCBEACH L: $(FC \text{ SOURCE} / 92 \text{ DAYS}) \times 79 \text{ DAYS} - (\text{TRAVEL TIME} \times \text{DISAPPEARANCE RATE})$
= Beach bacterial load for each source at low flow (79 days)

FCBEACH H: $(FC \text{ SOURCE} / 92 \text{ DAYS}) \times 13 \text{ DAYS} - (\text{TRAVEL TIME} \times \text{DISAPPEARANCE RATE})$
= Beach bacterial load for each source at high flow (13 days)

CURB COST: Cost for remedial measures to theoretically eliminate bacterial source.

BT/DOLLAR: Bacterial reduction per dollar spent on remedial measures.
= $(\text{SOURCE LO} + \text{SOURCE HI}) / \text{CURB COST}$

TP: Total phosphorus produced by source for the entire summer season.

TP/DOLLAR: Phosphorus reduction per dollar spent on remedial measures.
= $\text{TP} / \text{CURB COST}$

ANNUAL FC: Total annual fecal coliform production by source.

AFC BEACH: $\text{ANNUAL FC} - (\text{high flow travel time} \times \text{disappearance rate})$
= Estimated annual beach bacterial load for each source

DO RATE: Disappearance rate for bacteria as they downstream travel in watercourses:
0.0291 log units per hour (0.7 logs/day).

SEPTIC SYSTEM FAILURES: Modified after Hayman, 1989
The bacterial load is a product of:

NUMBER OF HOUSES,
NUMBER OF PEOPLE / HOUSE,
LITRES / PERSON OF DAILY WATER USE,
FECAL COLIFORMS / LITRE OF EFFLUENT,
FAULTY SYSTEMS ESTIMATED AT THREE PERCENT (3%),
NUMBER OF DAYS PER YEAR.

STORM WATER RUNOFF: Calculated in East Humber River watershed only. No stormwater outlets affect the beach water quality at Bruce's Mill or Albion Hills Conservation Areas.

Based on work by Marselek (et. al. 1985)
The bacterial load is a product of:

AREA OF THE TOWN IN HECTARES
 3.1×10^{10} FECAL COLIFORMS / HECTARE / YEAR

CURB MODEL CALCULATIONS

The model predicts bacteria transport to the beach and the beach bacterial densities for a range of discharge conditions.

Beach bacterial Impact in Dry and Wet Weather

The effects of combined upstream bacterial sources on the beach swimming area were simulated three ways in each watershed:

1. Summer dry weather (low flow) bacterial loads. 79 days
2. Summer wet weather (high flow) bacterial loads. 13 days
3. Total summer bacteria loads (the sum of 1 and 2). 92 days

The summer season is defined as June 15 to September 14 (92 days). This is standardized with the PLOP model (Ecologistics, 1988) to eliminate data conversions. During the summer, an estimated 13 days would have precipitation greater than 5mm, or enough to generate runoff from the study watersheds (D. Haley, MTRCA, pers. comm.). These 13 days are modelled to have wet weather or high flow conditions. Dry weather, or low flow conditions, occurs during the remaining 79 days.

SUMMER LOW FLOW SOURCES: All low flow bacterial sources delivered to the beach for 79 dry summer days.

SUMMER HIGH FLOW SOURCES: All high flow bacterial sources delivered to the beach for 13 wet summer days. This includes 13 days of bacterial input from the low flow sources.

PERCENT OF TOTAL CONTRIBUTION: Each source is divided by the sum of sources for each event.

SUMMER LOW FLOW MODEL: $(\text{SUM OF ALL LOW FLOW BACTERIAL SOURCES} / 79 \text{ DAYS}) / \text{DAILY DISCHARGE}$
= Beach bacterial concentration

SUMMER HIGH FLOW MODEL: $(\text{SUM OF ALL HIGH FLOW BACTERIAL SOURCES} / 13 \text{ DAYS}) / \text{DAILY DISCHARGE}$
= Beach bacterial concentration

APPENDIX 2

Bruce Creek CURB model

BACTERIAL LOAD FROM INDIVIDUAL FARM SOURCES

ACCESS

FARM	ACCESS L	ACCESS HI	COST	BT/\$		TP/\$		ANNUAL F	AFC BEAC
				REDUCTIO	TP	REDUCTIO			
1	4.43E+09	1.26E+09	800	1.58E+06	1.48	1.85E-03	3.572E+10	2.749E+10	
3	9.00E+10	2.169E+10	10500	4.34E+06	0.41	8.16E-05	1.800E+11	1.501E+11	
2	0	5.68E+09	3210	1.77E+06	0.303	9.44E-05	2.050E+11	6.723E+10	
5	2.34E+09	508567467	850	5.96E+05	0.2916	3.43E-04	7.06E+09	5.85E+09	
TOTAL	9.678E+10	2.914E+10	15360	1.90E+06	2.4806	1.61E-04		2.507E+11	

BARNYARD AND STACKS

FARM	BARN LO	BARN HI	COST	BT/\$		TP/\$		ANNUAL F	AFC BEAC
				REDUCTIO	TP	REDUCTIO			
1		0	14019	0.00E+00	6.7	4.78E-04	5.408E+11	4.162E+11	
4		3.539E+12	60000	5.90E+07	128.5	2.14E-03	4.754E+13	4.074E+13	
TOTAL		3.539E+12	74019	4.78E+07	135.2	1.83E-03		4.115E+13	

BRUCE CREEK - MANURE SPREADING BACTERIA RUNOFF MODEL

SEASON	VOM KG	FO/KG	% OF MANURE SPREAD	FARMS WINTER SPREAD	% OVER- SPREAD	AMOUNT OVERSP	DELIVERY RATIO	STORAGE SURVIVAL DAYS	T+G 83 SURVIVAL 10+15 RATE	FIELD SURVIVAL DAYS	T+G 83 SURVIVAL 10+15 RATE	TOTAL SURVIVAL RATE	TOTAL MANURE RUNOFF
SPRING	1823223.6	3.000E+10	0.45	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	1.01E+10 SPRING
SUMMER	1823223.6	3.000E+10	0.2	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	4.50E+09 SUMMER
FALL	1823223.6	3.000E+10	0.3	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	6.75E+09 FALL
WINTER	1823223.6	3.000E+10	0.05	0.57	1	1	0.01	25	0.01	7	2.75E-01	3.70E-03	5.13E+10 WINTER

NOTES: MANURE CALCULATIO 1.15x1.31x24xEAUxDAYS
FROM MOE/KEMPENFE = 1823223.6

EAU =
123

SURVIVAL RATES FROM THELIN AND GIFFORD 1983

BRUCE CREEK BACTERIAL TRANSPORT MODEL

WILDLIFE BACTERIAL LOAD

		SPRING	SUMMER	FALL	WINTER	TOTAL
WILDLIFE	INPUT 10%	5.500E+11	5.500E+11	5.500E+11	5.400E+11	2.190E+12
WILDLIFE	ALL AREAS	5.500E+12	5.500E+12	5.500E+12	5.400E+12	2.190E+13

SEPTIC SYSTEM FAILURE (3%) BACTERIAL LOAD

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC1 x % FAULTY x #DAYS

100 3 137 1.00E+07 0.03 365

= 4.500E+12

	SPRING	SUMMER	FALL	WINTER	TOTAL
SEPTIC SYSTEM 3%	1.125E+12	1.125E+12	1.125E+12	1.125E+12	4.500E+12

DO RATE 0.0291666

TRANSPORT MODEL

SUMMER	TIME	SEPTIC	WILDLIFE	GEESE	SPREADING
	HOURS				
FC		1.125E+12	5.500E+11	2.840E+12	4.50E+09
FCBEACH L	24	1.921E+11	2.088E+11	1.129E+11	
FCBEACH H	12.0	7.259E+10	5.455E+10	1.907E+10	2.01E+09
CURB COST		30000			
BT/DOLLAR		8.82E+06			
TP					
TP/DOLLAR					
ANNUAL FC		4.500E+12	2.322E+12		7.267E+10
AFC BEACH		2.010E+12	1.189E+12		3.248E+10

BRUCE CREEK BACTERIAL TRANSPORT MODEL

SUMMER LOW FLOW SOURCES		PERCENT OF TOTAL CONTRIBUTION
LIVESTOCK ACCESS	9.676E+10	20 %
SEPTIC FAILURES 3%	1.921E+11	39 %
WILDLIFE	2.068E+11	42 %
TOTAL	4.956E+11	

SUMMER HIGH FLOW SOURCES		PERCENT OF TOTAL CONTRIBUTION
LIVESTOCK ACCESS	2.914E+10	1 %
SPREADING + PASTUR	2.01E+09	0.05 %
YARDS & STACKS	3.539E+12	96 %
WILDLIFE	5.455E+10	1 %
SEPTIC FAILURES 3%	7.250E+10	2 %
TOTAL	3.697E+12	

TOTAL SUMMER SOURCES		PERCENT OF TOTAL CONTRIBUTION
LIVESTOCK ACCESS	1.259E+11	3 %
SPREADING + PASTUR	2.01E+09	0.05 %
YARDS & STACKS	3.539E+12	84 %
WILDLIFE	2.814E+11	6 %
SEPTIC FAILURES 3%	2.65E+11	6 %
TOTAL	4.193E+12	

TOTAL ANNUAL SOURCES		PERCENT OF TOTAL CONTRIBUTION
LIVESTOCK ACCESS	2.507E+11	1 %
SPREADING + PASTUR	3.248E+10	0.1 %
YARDS & STACKS	4.115E+13	92 %
WILDLIFE	1.169E+12	3 %
SEPTIC FAILURES 3%	2.010E+12	5 %
TOTAL	4.461E+13	

SUMMER LOW FLOW MODEL * Q=AVG AUG 1988

DISCHARG CMS	CUBIC METRES/DAY	TOTAL FC	DAILY FC	BEACH CONC FC/100ML
0.04	3456	4.956E+11	6.44E+09	186
0.06	5184	4.956E+11	6.44E+09	124 *
0.08	6912	4.956E+11	6.44E+09	93

SUMMER HIGH FLOW MODEL * Q=MAX SUMMER 1990

DISCHARG CMS	CUBIC METRES/DAY	TOTAL FC	DAILY FC	BEACH CONC FC/100ML
0.25	21600	3.697E+12	2.844E+11	1317
0.5	43200	3.697E+12	2.844E+11	658
1	86400	3.697E+12	2.844E+11	329 *

APPENDIX 3

Centreville Creek CURB model

BACTERIAL LOAD FROM INDIVIDUAL FARM SOURCES

ACCESS

FARM #	ACCESS L	ACCESS HI	COST	BT/\$		TP/\$		ANNUAL F	AFC BEAC
				REDUCTIO	TP	REDUCTIO			
1	0	8.230E+10	680	9.16E+07	1.15	1.69E-03	7.781E+11	8.713E+11	
3	7.15E+08	153787514	1700	9.05E+04	0.08	3.35E-05	1.65E+09	1.24E+09	
4	7.26E+09	2.51E+09	680	3.70E+06	0.701	1.03E-03	6.209E+10	2.611E+10	
5	5.035E+10	1.732E+10	7850	2.04E+08	4.01	4.72E-02	7.574E+11	3.228E+11	
6	1.16E+09	399410910	200	2.00E+06	0.269	1.35E-03	1.666E+10	7.10E+09	
7	2.582E+11	5.937E+10	1700	3.49E+07	0.06	3.35E-05	1.083E+12	7.534E+11	
9	6.22E+09	2.86E+09	6000	9.52E+05	0.1296	4.32E-05	9.137E+10	2.746E+10	
TOTAL	3.239E+11	1.449E+11	19810	7.79E+06	6.3724	3.42E-04		1.809E+12	

BARNYARD AND STACKS

FARM #	BARN LO	BARN HI	COST	BT/\$		TP/\$		ANNUAL F	AFC BEAC
				REDUCTIO	TP	REDUCTIO			
1		1.915E+12	13900	1.38E+08	9.1	6.55E-04	1.570E+13	1.355E+13	
2		5.090E+11	85860	5.93E+06	5.5	6.41E-05	7.089E+12	6.074E+12	
2		6.31E+09	30858	2.06E+05	1.00	3.26E-05	8.452E+10	5.529E+10	
3		9.428E+10	59352	1.59E+06	2.30	3.88E-05	1.515E+12	1.143E+12	
3		2.029E+10	0	1.93E+06	1.00	5.56E-05	5.446E+10	4.108E+10	
4		6.181E+12	13900	4.45E+08	3.5	2.52E-04	2.584E+13	1.078E+13	
5		1.023E+12	165988	6.16E+06	1.4	8.43E-06	3.039E+13	1.295E+13	
5		1.735E+11	0	7.21E+06	8	5.66E-05	3.819E+12	1.628E+12	
6		1.909E+12	6000	3.18E+08	6.7	1.12E-03	4.939E+13	2.105E+13	
7		7.515E+10	50815	1.48E+06	2.30	4.53E-05	1.150E+12	8.002E+11	
8		1.201E+12	85000	1.41E+07	73.50	8.65E-04	4.872E+13	1.342E+13	
TOTAL		1.311E+13	511473	2.56E+07	114.3	2.23E-04		8.149E+13	

MILKHOUSE

FARM #	MILK LO	MILK HI	COST	BT/\$		TP/\$		ANNUAL F	AFC BEAC
				REDUCTIO	TP	REDUCTIO			
2			5000	0.00E+00	13.74	2.75E-03			

CENTREVILLE CREEK - MANURE SPREADING BACTERIA RUNOFF MODEL

SEASON	VOM KG	FC/KG	% OF MANURE SPREAD	FARMS WINTER SPREAD	% OVER- SPREAD	AMOUNT OVERSP	DELIVERY RATIO	STORAGE SURVIVAL DAYS	T+G 83 10+15 RATE	FIELD SURVIVAL DAYS	T+G 83 10+15 RATE	TOTAL SURVIVAL RATE	TOTAL MANURE RUNOFF
SPRING	5028034.14	3.000E+10	0.45	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	3.14E+10 SPRING
SUMMER	5028034.14	3.000E+10	0.2	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	1.39E+10 SUMMER
FALL	5028034.14	3.000E+10	0.3	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	2.06E+10 FALL
WINTER	5028034.14	3.000E+10	0.05	0.57	1	1	0.01	25	0.01	7	2.75E-01	3.70E-03	1.59E+11 WINTER

NOTES: MANURE CALCULATION: $1.15 \times 1.31 \times 24 \times \text{EAU} \times \text{DAYS}$ EAU =
FROM MOE/KEMPENFEL = 5028034.1 381

SURVIVAL RATES FROM THELIN AND GIFFORD 1983

CENTREVILLE CREEK BACTERIAL TRANSPORT MODEL

WILDLIFE BACTERIAL LOAD

		SPRING	SUMMER	FALL	WINTER	TOTAL
WILDLIFE	INPUT 10%	1.110E+12	1.110E+12	1.090E+12	1.080E+12	4.390E+12
WILDLIFE	ALL AREAS	1.110E+13	1.110E+13	1.090E+13	1.080E+13	4.390E+13

SEPTIC SYSTEM FAILURE (3%) BACTERIAL LOAD

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC/I x % FAULTY x #DAYS						
	155	3	137	1.00E+07	0.03	365
=	6.97570E+12					

	SPRING	SUMMER	FALL	WINTER	TOTAL
SEPTIC SYSTEM 3%	1.744E+12	1.744E+12	1.744E+12	1.744E+12	6.976E+12

DO RATE 0.029166666

TRANSPORT MODEL

SUMMER	TRAVEL TIME IN HOURS	SEPTIC	WILDLIFE	GEESE	SPREADING
FC		1.744E+12	1.110E+12	8.270E+12	1.394E+10
FCBEACH L	18	5.095E+11	6.780E+11	3.538E+11	
FCBEACH H	9.0	1.378E+11	1.473E+11	5.973E+10	7.62E+09
CURB COST	50000				
BT/DOLLAR	1.29E+07				
TP					
TP/DOLLAR					
ANNUAL FC		6.978E+12	4.390E+12		2.251E+11
AFC BEACH		3.811E+12	2.399E+12		1.230E+11
AFC BT/\$		76228545			

CENTREVILLE CREEK BACTERIAL TRANSPORT MODEL

TOTAL SUMMER LOW FLOW SOURCES		%
LIVESTOCK ACCESS	3.239E+11	21.4 %
SEPTIC FAILURES 3%	5.095E+11	33.7 %
WILDLIFE	6.780E+11	44.9 %
TOTAL	1.511E+12	

TOTAL SUMMER HIGH FLOW SOURCES		%
LIVESTOCK ACCESS	1.449E+11	1.1 %
SPREADING + PASTURE	7.62E+09	0.1 %
YARDS & STACKS	1.311E+13	96.8 %
WILDLIFE	1.473E+11	1.1 %
SEPTIC FAILURES 3%	1.376E+11	1.0 %
TOTAL	1.355E+13	

TOTAL SUMMER SOURCES		%
LIVESTOCK ACCESS	4.688E+11	3.1 %
SPREADING + PASTURE	7.62E+09	0.05 %
YARDS & STACKS	1.311E+13	87.1 %
WILDLIFE	8.254E+11	5.5 %
SEPTIC FAILURES 3%	6.471E+11	4.3 %
TOTAL	1.506E+13	

TOTAL ANNUAL SOURCES		%
LIVESTOCK ACCESS	1.809E+12	2.0 %
SPREADING + PASTURE	1.230E+11	0.1 %
YARDS & STACKS	8.149E+13	90.9 %
WILDLIFE	2.399E+12	2.7 %
SEPTIC FAILURES 3%	3.811E+12	4.3 %
TOTAL	8.963E+13	

SUMMER LOW FLOW MODEL				Q=AVG AUG 1988
DISCHARGE	CUBIC	TOTAL FC	DAILY FC	BEACH CONC
CMS	METRES/DAY			FC/100ML
0.06	5184	1.511E+12	1.963E+10	379
0.12	10368	1.511E+12	1.963E+10	189 *
0.18	15552	1.511E+12	1.963E+10	126

SUMMER HIGH FLOW MODEL				Q=MAX SUMMER 1988
DISCHARGE	CUBIC	TOTAL FC	DAILY FC	BEACH CONC
CMS	METRES/DAY			FC/100ML
0.25	21600	1.355E+13	1.042E+12	4824
0.5	43200	1.355E+13	1.042E+12	2412 *
0.75	64800	1.355E+13	1.042E+12	1608

APPENDIX 4

East Humber River CURB model

BACTERIAL LOAD FROM INDIVIDUAL FARM SOURCES

ACCESS

FARM #	ACCESS LO	ACCESS HI	COST	BT/\$		TP/\$		ANNUAL FC	AFC BEACH
				REDUCTION	TP	REDUCTION	TP		
2	3.57E+09	2.12E+10	12900	1.84E+06	10.20	7.91E-04	7.96E+12	2.42E+11	
3	1.52E+08	9.01E+06	425	2.12E+04	0.08	1.34E-04	3.76E+09	1.07E+08	
4	8.26E+08	3.04E+07	9500	3.20E+03	0.3885	4.09E-05	9.41E+09	3.50E+08	
5	2.97E+08	1.54E+09	2700	5.71E+05	0.827	2.32E-04	3.28E+11	1.07E+10	
6	4.36E+08	2.77E+09	6125	4.52E+05	1.421	2.32E-04	1.05E+12	2.62E+10	
7	8.20E+07	8.74E+08	5250	1.28E+05	0.88	1.68E-04	6.00E+11	9.32E+09	
8	0.00E+00	2.82E+09	2700	1.05E+08	0.64	2.38E-04	1.71E+11	3.90E+10	
9	1.35E+08	1.46E+09	9500	1.54E+05	1.48	1.53E-04	1.09E+12	1.89E+10	
11	1.31E+10	9.86E+09	12900	7.49E+05	0.80	4.62E-05	4.43E+11	1.01E+11	
14	4.61E+09	7.14E+09	1	7.14E+09	1.12	1.12E+00	7.56E+11	8.24E+10	
15	1.97E+11	1.04E+11	2608	4.00E+07	4.58	1.78E-03	3.42E+12	1.02E+12	
16	1.94E+11	9.61E+10	6100	1.58E+07	10.19	1.67E-03	6.89E+12	2.20E+12	
17	9.59E+10	4.74E+10	17750	2.67E+06	7.08	3.99E-04	2.10E+12	6.70E+11	
18	1.80E+11	8.34E+10	4400	1.90E+07	6.13	1.39E-03	1.09E+12	3.96E+11	
19	1.60E+11	5.30E+10	9500	5.57E+06	1.71	1.80E-04	1.16E+12	5.55E+11	
20	6.13E+08	2.80E+07	3550	7.33E+03	0.24	6.85E-05	5.88E+09	2.50E+08	
21	2.61E+08	1.03E+09	170	6.08E+06	0.85	4.99E-03	4.76E+11	2.03E+10	
22	1.33E+11	4.69E+10	170	2.76E+08	0.63	3.69E-03	1.13E+12	5.40E+11	
23	5.99E+10	5.07E+10	3380	1.50E+07	7.32	2.17E-03	5.28E+12	1.05E+12	
24	3.03E+07	1.10E+09	5250	2.10E+05	6.56	1.25E-03	5.28E+12	2.29E+10	
TOTAL	1.04E+12	5.31E+11	114879	4.62E+06	62.6826	5.48E-04		7.01E+12	

BARNYARD AND STACKS

FARM #	BARN LO	BARN HI	COST	BT/\$		TP/\$		ANNUAL FC	AFC BEACH
				REDUCTION	TP	REDUCTION	TP		
1	3.14E+08	0	1.63E+05	2	4.85E-05	3.49E+11	9.28E+09		
1	2.05E+10	127877	1.61E+05	4.2	3.28E-05	1.59E+13	4.24E+11		
2	8.64E+10	113665	7.60E+05	48	4.22E-04	3.56E+13	1.08E+12		
3	6.37E+10	47501	1.34E+08	2.30	4.84E-05	2.66E+13	7.57E+11		
5	1.12E+11	24095	4.66E+06	93.8	3.89E-03	4.17E+13	1.36E+12		
6	5.77E+10	122272	4.72E+05	12.2	9.98E-05	2.56E+13	6.37E+11		
10	2.79E+10	127877	2.18E+05	0.6	4.69E-06	8.58E+12	2.28E+11		
12	3.51E+09	4238	8.29E+05	3	7.08E-04	1.46E+12	3.88E+10		
13	6.76E+11	13342	5.06E+07	9	6.75E-04	3.05E+13	8.51E+12		
14	2.73E+11	68437	3.98E+06	24.90	3.64E-04	3.20E+13	3.48E+12		
14	2.70E+08	0	3.99E+06	0.00	3.64E-04	1.17E+10	1.28E+09		
14	1.21E+07	0	3.99E+06	3.00	4.08E-04	3.84E+10	4.19E+09		
15	1.33E+12	52495	2.53E+07	15.90	3.03E-04	4.90E+13	1.46E+13		
15	7.40E+08	0	2.53E+07	0.00	3.03E-04	1.17E+10	3.49E+09		
16	6.03E+11	109002	5.54E+06	12.40	1.14E-04	2.70E+12	8.61E+11		
18	6.21E+11	113762	5.46E+06	13.00	1.14E-04	3.04E+13	1.11E+13		
19	9.32E+10	92910	1.00E+06	17.70	1.91E-04	2.31E+12	1.10E+12		
20	1.12E+09	81455	1.37E+04	0.70	8.59E-06	1.85E+12	7.88E+10		
21	5.32E+09	5308	1.00E+06	0.40	7.54E-05	1.10E+12	4.88E+10		
22	3.06E+10	31157	9.81E+05	93.80	3.01E-03	1.88E+12	8.98E+11		
23	3.25E+12	90227	3.00E+07	7.00	7.76E-05	3.26E+13	6.49E+12		
24	1.61E+10	91515	1.76E+05	6.56	7.17E-05	4.33E+13	1.88E+11		
25	7.64E+11	89419	8.55E+06	50.00	5.59E-04	4.33E+13	0.00E+00		
TOTAL		8.03E+12	1406554	5.71E+06	420	2.99E-04		5.20E+13	

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

MILKHOUSE

FARM #	MILK LO	MILK HI	COST	BT/\$		TP/\$		ANNUAL FC	AFC BEACH
				REDUCTION	TP	REDUCTION	TP		
2	9.85E+06	5.85E+07	5000	1.17E+04	33.00	6.60E-03	5.32E+10	1.62E+09	
24	1.69E+05	3.64E+07	5000	7.27E+03	23.00	4.60E-03	3.35E+10	1.45E+08	
18	0.00E+00	3.65E-01	5000	7.30E-05	12.00	2.40E-03	1.00E+00	3.65E-01	
TOTAL	1.00E+07	9.48E+07	15000	6.32E+03	68	4.53E-03		1.76E+09	

EAST HUMBER RIVER - MANURE SPREADING BACTERIA RUNOFF MODEL

SEASON	VOM KG	FC/KG	% OF MANURE SPREAD	% OF FARMS SPREADING	% OVER- SPREAD	AMOUNT OVERSP	DELIVERY RATIO	STORAGE DAYS	T+G 83 SURVIVAL RATE	FIELD SURVIVAL DAYS	T+G 83 SURVIVAL RATE	TOTAL SURVIVAL RATE	TOTAL MANURE RUNOFF
SPRING	38590820	3.00E+10	0.45	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	2.47E+11
SUMMER	38590820	3.00E+10	0.2	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	1.10E+11
FALL	38590820	3.00E+10	0.3	1	0.05	0.25	0.01	25	0.01	7	2.75E-01	3.70E-03	1.65E+11
WINTER	38590820	3.00E+10	0.05	0.67	1	1	0.01	25	0.01	7	2.75E-01	3.70E-03	1.25E+12
													2.47E+11
													1.10E+11
													1.65E+11
													1.25E+12

NOTES: MANURE CALCULATIO : 1.15x1 31x24xEAUxDAYS EAU=3000 IN EHR
(FROM MOE/KEMPENFELT) DAYS=365

THELIN AND GIFFORD 1983

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

BACTERIA LOAD FROM SEPTIC SYSTEM FAILURES

SEPTIC SYSTEMS

TOWN	SEPTIC LO	SEPTIC HI	COST	BT/\$ REDUCTIO	# FAULTY	ANNUAL F	AFC BEAC
KING CITY	1.09E+09	2.32E+10	540000	4.51E+04	54	8.110E+13	6.442E+11
OAK RIDGE	4.55E+08	1.55E+10	0	0.00E+00	0	8.641E+13	4.289E+11
NOBLETO	1.76E+10	6.97E+10	300000	2.91E+05	30	4.536E+13	1.931E+12
EHRW	7.65E+10	1.45E+11	300000	7.38E+05	30	4.500E+13	4.011E+12
TOTAL	9.56E+10	2.53E+11	1140000	3.06E+05	84	2.58E+14	7.02E+12

BACTERIA LOAD FROM STORMWATER RUNOFF

STORMWATER

TOWN	STORM HI	ANNUAL F	AFC BEACH
KING CITY	2.863E+10	1.442E+13	1.145E+11
OAK RIDGES	1.56E+10	1.259E+13	6.248E+10
NOBLETON	9.64E+10	9.052E+12	3.854E+11
TOTAL	1.41E+11	3.61E+13	5.62E+11

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

BACTERIAL LOAD CALCULATIONS FOR SEPTIC SYSTEM FAILURES AND STORMWATER RUNOFF

KING CITY

SEPTIC SYSTEM FAILURE (3%)

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC/I x % FAULTY x #DAYS
 1802 3 137 1.00E+07 0.03 365
 = 8.110E+13 FC/YR * FROM HAYMAN, 1989

STORM WATER RUNOFF

TOWN AREA
 FC LOAD = HECTARES x FC/HA/YR * * FROM MARSELAK, 1985
 485 3.100E+10
 = 1.442E+13 FC/YR

OAK RIDGES

SEPTIC SYSTEM FAILURE (3%)

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC/I x % FAULTY x #DAYS
 1920 3 137 1.00E+07 0.03 365
 = 8.641E+13 FC/YR * FROM HAYMAN, 1989

STORM WATER RUNOFF

TOWN AREA
 FC LOAD = HECTARES x FC/HA/YR * * FROM MARSELAK, 1985
 406 3.100E+10
 = 1.259E+13 FC/YR

NOBLETON

SEPTIC SYSTEM FAILURE (3%)

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC/I x % FAULTY x #DAYS
 1008 3 137 1.00E+07 0.03 365
 = 4.536E+13 FC/YR * FROM HAYMAN, 1989

STORM WATER RUNOFF

TOWN AREA
 FC LOAD = HECTARES x FC/HA/YR * * FROM MARSELAK, 1985
 292 3.100E+10
 = 9.052E+12 FC/YR

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

EAST HUMBER RIVER WATERSHED

SEPTIC SYSTEM FAILURE (3%)

FC LOAD = # HOUSES x PEOPLE/HOUSE x I/PERSON x FC/I x % FAULTY x #DAYS

1000 3 137 1.00E+07 0.03 365

= 4.500E+13 FC/YR * FROM HAYMAN, 1989

BACTERIAL TRANSPORT MODEL
FOR SEPTIC SYSTEM FAILURES AND STORMWATER RUNOFF

KING CITY

	SUM FC	TIME HOURS	SEPTIC	STORMWATER
FC	2.388E+13		2.0275E+13	3.6038E+12
		51320	KING CITY	KING CITY
FCBEACH L		144.0	1.09E+09	
FCBEACH	5.189E+10	72.0	2.326E+10	2.863E+10
CURB COS	540000		540000	
BT/DOLLAR			4.31E+04	
		54	SYSTEMS	
		10000	COST/	
ANNUAL F	9.551E+13		8.1098E+13	1.4415E+13
AFC BEAC	7.587E+11		6.4419E+11	1.1450E+11

OAK RIDGES

	SUM FC	TIME HOURS	SEPTIC	STORMWATER
FC	2.475E+13		2.1602E+13	3.1485E+12
		57000	OAK RIDGE	OAK RIDGES
FCBEACH L		158.0	4.55E+08	
FCBEACH	3.111E+10	79.0	1.549E+10	1.562E+10
CURB COS	0		0	
BT/DOLLA	0.00E+00		0.00E+00	
		0	SYSTEMS	
		10000	COST/	
ANNUAL F	9.899E+13		8.6409E+13	1.2580E+13
AFC BEAC	4.914E+11		4.2894E+11	6.248E+10

NOBLETON

	SUM FC	TIME HOURS	SEPTIC	STORMWATER
FC	1.380E+13		1.1341E+13	2.2630E+12
		34000	NOBLETON	NOBLETON
FCBEACH L		94.0	1.759E+10	
FCBEACH	1.661E+11	47.0	8.975E+10	9.835E+10
CURB COS	300000		300000	
BT/DOLLA	5.54E+05		2.32E+05	
		30	SYSTEMS	
		10000	COST/	
ANNUAL F	5.442E+13		4.5365E+13	9.0520E+12
AFC BEAC	2.317E+12		1.9315E+12	3.8540E+11

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

EAST HUMBER RIVER WATERSHED

	SUM FC	TIME	SEPTIC
		HOURS	
FC			1.125E+13
			EHRW
FCBEACH L	72.0	7.646E+10	
FCBEACH H	38.0	1.448E+11	
CURB COST		300000	
BT/DOLLAR		4.83E+05	
SYSTEMS		30	
COST/		10000	
ANNUAL FC		4.500E+13	
AFC BEACH		4.011E+12	

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

WILDLIFE BACTERIAL LOAD

		SPRING	SUMMER	FALL	WINTER	ANNUAL
WILDLIFE	INPUT 10%	2.540E+12	2.540E+12	2.520E+12	2.490E+12	1.009E+13
WILDLIFE	ALL AREAS	2.540E+13	2.540E+13	2.520E+13	2.490E+13	1.009E+14

TRANSPORT MODEL

SUMMER	TIME	STORM			
	HOURS	WATER	SEPTIC	WILDLIFE	SPREADING
FC				2.540E+12	1.100E+11
FCBEACH	72		9.580E+10	1.726E+10	
FCBEACH	36	1.408E+11	2.533E+11	3.270E+10	9.80E+09
CURB COST			1140000		
BT/DOLLAR			3.08E+05		
ANNUAL FC		3.805E+13	2.579E+14	1.009E+13	1.772E+12
AFC BEACH		5.824E+11	7.018E+12	8.993E+11	1.579E+11
AFC BT/\$			8.15E+08		

EAST HUMBER RIVER BACTERIAL TRANSPORT MODEL

TOTAL SUMMER LOW FLOW SOURCES		% SOURCE
LIVESTOCK ACCESS	1.043E+12	90.2 %
MILKHOUSE WASHWATER	1.00E+07	0.00
SEPTIC FAILURES 3%	9.580E+10	8.3 %
WILDLIFE	1.728E+10	1.5 %
TOTAL	1.158E+12	

TOTAL SUMMER HIGH FLOW SOURCES		% SOURCE
LIVESTOCK ACCESS	5.311E+11	5.9 %
MILKHOUSE WASHWATER	6.37E+07	0.00
SPREADING + PASTURE	9.80E+09	0.1 %
YARDS AND STACKS	8.034E+12	89.3 %
SEPTIC FAILURES 3%	2.533E+11	2.8 %
STORMSEWER RUNOFF	1.408E+11	1.6 %
WILDLIFE	3.270E+10	0.4 %
TOTAL	9.002E+12	

TOTAL SUMMER SOURCES		% SOURCE
LIVESTOCK ACCESS	1.574E+12	15.5 %
MILKHOUSE WASHWATER	7.37E+07	0.00
SPREADING + PASTURE	9.80E+09	0.1 %
YARDS AND STACKS	8.034E+12	79.1 %
SEPTIC FAILURES 3%	3.489E+11	3.4 %
STORMSEWER RUNOFF	1.408E+11	1.4 %
WILDLIFE	4.998E+10	0.5 %
TOTAL	1.018E+13	

TOTAL ANNUAL SOURCES		% SOURCE
LIVESTOCK ACCESS	7.008E+12	10.4 %
MILKHOUSE WASHWATER	1.76E+09	0.00
SPREADING + PASTURE	1.579E+11	0.2 %
YARDS AND STACKS	5.198E+13	78.9 %
SEPTIC FAILURES 3%	7.018E+12	10.4 %
STORMSEWER RUNOFF	5.824E+11	0.8 %
WILDLIFE	8.993E+11	1.3 %
TOTAL	6.781E+13	

SUMMER LOW FLOW MODEL				* Q=AVG AUG 1988
DISCHARGE	CUBIC	TOTAL FC	DAILY FC	BEACH CONC
CMS	METRES/DAY			FC/100ML

0.1	8640	1.158E+12	1.501E+10	174
0.212	18318.8	1.158E+12	1.501E+10	82 *
0.3	25920	1.158E+12	1.501E+10	58

SUMMER HIGH FLOW MODEL				* Q=MAX SUMMER 198
DISCHARGE	CUBIC	TOTAL FC	DAILY FC	BEACH CONC
CMS	METRES/DAY			FC/100ML

0.3	25920	9.002E+12	6.924E+11	2871
0.858	74131.2	9.002E+12	6.924E+11	934 *
1	86400	9.002E+12	6.924E+11	801

APPENDIX 5

Wildlife Bacterial Estimates

WILDLIFE BACTERIAL POLLUTION SOURCES

The following model calculations are discussed in the 1990 Rural Beaches Project annual report.

Fecal coliform loading rates for beaver and muskrat, were calculated with the following formula:

FECAL COLIFORM

LOAD = (FECAL COLIFORM CONCENTRATION/G OF FECES) X (FECAL OUTPUT IN G/DAY/ANIMAL) X (# OF ANIMALS) X (# OF DAYS) WHERE;

NUMBER

OF ANIMALS:

length of watercourse in habitat area x density estimate

72 and 23 geese were observed at Albion Hills and Bruce's Mill Conservation Areas respectively, in June 1990.

NUMBER

OF DAYS:

92 days (PLOP model, Ecologistics, 1988)

Estimated number
of animals:

0.64 beavers per kilometre of watercourse (Semyonoff, 1951).

Estimated watercourse length for beaver habitat		Number of animals
Centreville Creek	- 22 km	14
East Humber River	- 44 km	28
Bruce Creek	- 3 km	2

11 muskrat per kilometre of watercourse (Brooks & Dodge, 1986)

Estimated watercourse length for muskrat habitat		Number of animals
Centreville Creek	- 22 km	242
East Humber River	- 53 km	583
Bruce Creek	- 14 km	154

FECAL OUTPUT:

657g per beaver per day (Ingle-Sidorowicz, 1982; Boutin & Birkenholtz, 1987).

100g per muskrat per day. Based on information available for other herbivores of similar size.

100g per goose per day (Pitt, pg 20., 1980).

BACTERIAL

CONCENTRATION:

3.6×10^8 fecal coliforms per gram of fecal material for beaver and muskrat (Young et al., 1988).

7.8×10^8 fecal coliforms per gram of fecal material for geese (Young et al., 1988).

An estimated 10% of all fecal coliform bacteria produced was released into the watercourse (M. Young, MOE, pers. comm.). For geese, the application factor was 5%.

REFERENCES

- Boutin, S. and D. Birkenholtz, 1987. Muskrat and Round-tailed Muskrat. In M. Novak, J.A. Baker, M.E. Obbard and B. Malloch, eds. Wild Furbearer Management and Conservation in North America. Ontario Trappers Association, North Bay, Ontario.
- Brooks, R.P. and W.E. Dodge, 1986. Estimation of habitat quality and summer population density for muskrats on a watershed basis. Journal of Wildlife Management, 50(2):269-273.
- Ecologistics Limited, 1988. PLOP - A Planning Tool to Evaluate the Pollution Potential of Livestock Operations in Southern Ontario. Waterloo, Ontario.
- Hayman, D.G., 1989. A Clean Up Rural Beaches (CURB) Plan for Fanshawe, Pittock and Wildwood Reservoirs. In the Upper Thames River Conservation Authority. London, Ontario.
- Hubbard, R., P. Mar, H. Power, and T. Ryan, 1988. Metropolitan Toronto and Region Conservation Authority. Rural Beaches Impact Study 1987-88. Downsview, Ontario.
- Ingle-Sidorowicz, H.M., 1982. Beaver increase in Ontario: Result of changing environment. Mammalia, 46(2):167-175.
- Marsalek, J., V. Panu, and H.Y.F. Ng. 1985. Storm Runoff Study of the Newton Urban Catchment. Urban Hydrology Study of the Waterford River Basin. Technical Report No. VHS_WRB 1.5. Environment Canada.
- Pitt, Robert, 1982. Urban Bacteria Sources and Control by Street Cleaning in the Lower Rideau River Watershed. Ottawa, Ontario.
- Toombs, M. 1990. Ontario Ministry of Agriculture and Food. Personal communication. Newmarket, Ontario.
- Young, M. 1990. Ministry of the Environment. Personal Communication. Rexdale, Ontario.
- Young, M., E. Harris and P. Seyfried, 1988. Pathogen/Indicator Bacterial Relationships and their Relevance to Recreational Waters Introduction. Ministry of the Environment Report awaiting publication.

